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TRACE COMPUTER MODEL USER'S GUIDE.(U)

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TRACE COMPUTER MODEL USER'S GUIDE

The BDM Corporation
7915 Jones Branch Drive
McLean, Virginia 22102

12 October 1979

Topical Report for Period March 1978—February 1979

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This document specifies and describes the input data, procedures and job control language needed to use the TRACE digital computer simulation model as well as outputs that are available. TRACE (TCOR Revised to Assess Communications Effectiveness) is an extension and enhancement of TCOR, a theater level tactical combat simulation, emphasizing tactical communications performance in a mixed conventional and nuclear conflict environment. Introductory material is included to minimize reference to other TCOR and TRACE documentation.

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JOB

PREFACE

This report presents, in a single document, all of the information required to input data, execute and obtain results from the TRACE digital computer simulation model. This work was authorized and sponsored by the Defense Nuclear Agency under RDT&E RMSS code B3630 78464 099QAXCA11002 H2590D.

Dr. William Sweeney, Jr. was the program manager for this effort while Captain Frank Eisenbarth of DNA (VLIS) served as the Contracting Officer's Representative.

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SECTION 1
INTRODUCTION AND OVERVIEW

1.1 GENERAL

The purpose of this document is to provide the user with an overview of the TRACE simulation and a detailed description of how to run it. TRACE is currently undergoing further development to enhance the simulation of communications equipment, nuclear effects, and logistics. Although a significant amount of design work has been accomplished, the new inputs and outputs related to these enhancements have not yet been installed. Therefore, this manual will be concerned only with the existing version of TRACE which is installed and running at the Air Force Weapons Lab (AFWL).

This chapter will present some background information and describe key characteristics of TRACE. The following chapters will discuss the inputs to the simulation, the job control language necessary to run the simulation, and the outputs from the simulation.

1.2 BACKGROUND

TRACE is a theater level tactical combat simulation with emphasis on the communications aspects. It is being designed and developed at BDM for the Defense Nuclear Agency. The origins of TRACE lie in the TCOR and COMBAT II simulations also developed for DNA by BDM to study conventional and nuclear operations at the theater level. The application of COMBAT II was limited by its high level of aggregation, confinement of ground force maneuvers to one dimension, and idealization of command and control processes. The development of TCOR was initiated to correct these and other deficiencies. TRACE extends TCOR to represent and study communications in greater detail. Many key ideas came from a preliminary design study for a Combined Arms Simulation Model (CASM) which BDM performed for the USAF (AF/SA). This study utilized the concept of a hexagonal grid to provide for two-dimensional movement of ground forces and developed concepts for much improved software using top-down structured programming techniques. The feasibility of these concepts was demonstrated by the development of TCOR I for DNA.

The work on TCOR I has spawned a new generation of combat simulations, known as the METRIC family of simulations, under continuing development and utilization at BDM. These simulations are centered on players which represent decision-making force elements. This type of structure permits operationally recognizable battlefield situations and interactions. Actions and their consequences are explicitly simulated instead of implicitly contained in numerous equations. Mental and physical processes are separated to provide a distinction between actual combat situations and possibly incomplete or inaccurate perceptions of the situations. This permits a more realistic treatment of command, control, and intelligence processes. The use of a hexagonal coordinate system allows two-dimensional maneuver of ground combat units thereby improving the realism of unit interactions. A man-in-the-loop capability permits tne user to specify operations orders for higher level command units and thus interact directly with the simulation.

A brief summary of the members of the METRIC family of simulations follows. They span a hierarchy from detailed AAA gun vs. aircraft up through a theater level perspective. TRACE is currently a descendent of TCOR evolving from a version that lies between TCOR IIA and the completion of TCOR IIB.

Table 1. Summary of METRIC family simulations.

THE METRIC FAMILY OF SIMULATIONS
(December 1978)

TCOR I — A simulation test bed developed to demonstrate software and modeling concepts of the METRIC Family.

CLEW I — An extension of TCOR I to represent corps level electronic warfare operations. Emphasis on value of ESM to corps and division maneuver planning. Combat interactions resolved at brigade/regiment level. All command and control accomplished by man-in-the-loop means.

CLEW II An enhancement of CLEW I to include non-ESM airborne and groundbased sensors. Combat interactions resolved at battalion level.

TCOR II A Initial stage of TCOR development intended to support analyses. Principal emphasis on ground maneuver and fire support operations within a detailed corps area where combat interactions are resolved at company/battery level. Command and control by man-in-the-loop at corps level and by automated means at lower echelons.

WARRANT An application of TCOR II A (detailed corps) simulation enhanced to include Red electronic warfare operations against Blue communication networks.

TRACE An application of TCOR II enhanced to include detailed representation of communications and their vulnerability to nuclear weapons effects, in particular EMP. TRACE includes the EW operations of WARRANT.

INWARS A simulation of integrated theater level nuclear, chemical, and conventional warfare under development for the U.S. Army Focus is on command and control processes at division and above. Combat interactions will be resolved at the brigade/regiment level.

MADEM A detailed simulation of Blue area air defense systems engaging penetrating Red aircraft. Resolution is at the aircraft flight and SAM battery level.

TAC REPELLER/ TAC GUNNER Highly detailed simulations of Red air defense systems engaging penetrating Blue aircraft. Resolution is at the individual aircraft vs. individual missile/gun level.

TCOR II B An extension of TCOR II A in development to include enhancement of nuclear effects, logistics, air operations, target acquisition, and weapons assignment processes.

1.3 DESCRIPTION OF THE SIMULATION

TRACE is designed to simulate a theater level combined conventional and nuclear conflict between NATO and WARSAW PACT forces in Central Europe. The specific scenario, including the command and control structure, unit descriptions, weapon system characteristics, and operations orders is input by the user.

TRACE has the capability to simulate a variety of military operations including meeting engagements and breakthroughs. The user, acting as a man-in-the-loop, inputs the type of operation as well as detailed operations orders for higher level commanders. The simulation then adapts and refines these orders for each lower level of command.

The lowest level of command represented in TRACE is the battalion, with its resources distributed among a number of company centers, one of which is a headquarters company. Higher levels of command are represented explicitly by subordinate headquarters companies. Company level units move and engage in combat in response to the local combat situation and orders from their commanders. The movement and resources of a command unit are calculated by aggregating the movement and resources of subordinates.

Company level units are characterized by the number of radios, tanks, artillery tubes, APC's (ATU's), and ammunition they possess. These factors attribute to the unit some capability to communicate, move, shoot, and observe its surroundings. By varying this input, the user can represent various types of mechanized infantry, armored cavalry, armor, or artillery units.

Combat support is represented explicitly by artillery units, electronic warfare (EW) units, and close air support (CAS). Currently, tactical air missions, other than close air support, are treated implicitly to determine the level of CAS provided.

Communications can be simulated at two different levels of detail, depending on user input. Several distinct types of nets are represented. Message types include operations orders, status reports, intelligence reports, close air support requests, and artillery support requests.

EW contermeasures against communications, including jamming, direction finding, and signal intelligence can also be simulated. Communications passes between the command levels and affects the actions of the units at these levels.

Each command level in TRACE is capable of both mental and physical processes. Command units make decisions based on their perceptions of the combat situation. These perceptions need not be in full agreement with the actua situation. Each ground unit, through its own sensors and through direct observation of ground movement and combat, collects information on enemy forces in the area. This information may be used within the unit and also transmitted via a communications network to higher commanders.

TRACE uses a stochastic representation of critical processes to reflect the inherent uncertainty in combat interactions. Users desiring to analyze a range of possible outcomes have two alternatives. One is to resimulate the same scenario with a different random seed to generate different random draws. The other possibility is to make slight variations in the initial or subsequent operations orders input by the man-in-the-loop.

1.4 SIMULATION ARCHITECTURE

The TRACE simulation has been implemented using the latest techniques of top-down structured programming. This approach makes for a logical and coherent architecture which facilitates the design and development process. The modularity in structure also simplifies the introduction of improvements and modifications.

The design of TRACE is based on the philosophy that the decision-making units described in the scenario are the driving factors, rather than the processes they perform. These units are called players and therefore the simulation is called player-centered. All units at the battalion level of command and higher are players, whereas company level units have a more limited decision-making capability and are called pseudo-players. TRACE deals with the interactions of players, and this is reflected in the input. Instead of diverse coefficients for arrays of equations, the primary inputs consist of command and control and unit descriptions.

The processes by which players interact in TRACE are broken down into events. An event represents some change in the overall status of the simulation which occurs at an instantaneous point in time or over a small incremental time step. Some events are discrete and occur just once after being scheduled, while others are continuous and occur repeatedly at fixed time intervals from the time they are scheduled until they are cancelled. Players interact by scheduling events for themselves or other players. Corresponding to each event, there are one or more subroutines which simulate it.

Another characteristic of the philosophy behind TRACE is stimuli-driven reactions or action-reaction dynamics. This simply means that certain processes will be simulated only in response to specific actions or stimuli which trigger the processes. This concept is implemented through the event structure, which causes new events to be scheduled during the simulation of a given event. For example, if a player is not in range of any enemy units, no combat event will be scheduled for him. Suppose, however, that an enemy unit moves into range. As the movement is simulated, an event corresponding to a possible observation of the enemy unit will be scheduled for the player. In response to an observation, the player may decide to engage the enemy unit in combat and schedule a combat event for himself. This approach makes the simulation execution considerably more efficient than it would be if all possible processes were executed for each player at constant time intervals. In addition, the design process is simplified. The designer can restrict his attention to one small section of each process at a time by listing all possible reactions to a given event and then defining new events corresponding to those reactions whose explicit simulation is appropriate to the overall level of detail.

All of the data which defines the current status of a TRACE simulation is maintained in a dynamically allocated storage array. Various types of data structures, linked together by pointers, record unit status, command and control relationships, future events which have been scheduled, operations orders, material strengths and losses, messages in transit, perceptions of enemy units, targets acquired, weapons allocated, etc. Numerous list processing routines add or delete blocks from specific lists, acquiring or releasing storage space, as the simulation progresses.

The TRACE simulation is driven by a set of subroutines called the Simulation Control Software (SCS). The SCS maintains the dynamically allocated storage array, sorts discrete events by the time they are to be simulated, sorts continuous events by their time intervals, and calls the event processing modules in the proper sequence. Thus, the SCS serves as a storage manager and a time-keeper. No event processing can be initiated except through the SCS. This requirement has the effect of decoupling the interactions between units and enforcing the modular structure of the code. If one event causes another event to be scheduled for some future time, the SCS prevents a routine which is processing the first event from simply calling a routine to process the second event. The flow of control must pass through the SCS routines which ensure that any intervening events are simulated first.

1.5 MAJOR FUNCTIONAL MODULES

The event processing subroutines in TRACE are separated into ten major modules: PLAN, PERCEPT, PONDER, MOVE, COMBAT, FIRE, SHOOT, COMMO, ASSIGN, and TIMEOUT. The following paragraphs give brief descriptions of each of these major modules.

1.5.1 Maneuver Planning Module - PLAN

This module contains the routines associated with planning a military operation based on an operations order. This includes refining orders to pass down to subordinates what their part of the operation is to be. As the situation develops, minor changes to the plan are carried out in the PONDER module.

1.5.2 Sensory Perception Module - PERCEPT

This module is concerned with simulating all the relevant capabilities of a unit to receive information or react to input stimuli. This input includes visual sightings, receipt of messages, and electronic or mechanical detection of phenomena. Perceptions simulated by this module are placed on a queue for later response under the PONDER module.

1.5.3 Information Fusion and Decision-Making Module - PONDER

This module is concerned with acting upon all if the input stimuli received from the PERCEPT module, or special stimuli initiated by another module. The unit's status is examined, and proper responses are scheduled.

1.5.4 Non-combat Ground Movement Module - MOVE

Movement of units that are not in combat is processed through this module. The units move in accordance with guidelines contained in their operations orders, such as location of objective or phaseline, time requirements, and lateral boundaries. Other factors, such as the location of nearby units and terrain requirements, are also considered.

1.5.5 Ground Combat Module - COMBAT

This module contains the routines which deal with those phenomena occurring in direct fire ground combat interactions between opposing units, including combat movement. Events processed in this module are continuous events; i.e., this module is time-stepped.

1.5.6 Indirect Artillery Fire Module - FIRE

This module handles all of the processing requirements necessary to queue up artillery requests at a fire direction center, subsequently to service those requests by firing batteries, and to assess the results of the fire mission in terms of casualties caused and ammunition expended.

1.5.7 User Directed Nuclear Strikes - SHOOT

This module causes a nuclear strike to be executed at the direction of the TRACE user. The strike will occur in a designated level 3 hex. (See Appendix A for a discussion of hex levels.)

1.5.8 Communications Module - COMMO

This module is concerned with simulating the transmission of messages from one unit to another. In addition, the module contains the code concerned with direction finding, intercepting, and jamming procedures.

1.5.9 Temporary Game Timeout Module - TIMEOUT

This module is used to record snapshots of data structures for future analysis or to perform a check-point/restart operation for possible future reruns of the model without having to restart from the very beginning.

1.5.10 Reassignment of Units - ASSIGN

This module controls the reassignment or reorganization of force structures. It processed the assumption of command by another company when a headquarters company is lost and it accepted time oriented, user directed reorganization for task directed operations.

1.6 SIMULATION JOB CONTROL PROCESS

An overview of the TRACE simulation process is shown in Figure 1. The process consists of two distinct phases, initialization and execution. During initialization, the combat scenario is defined by inputting the unit descriptions, weapon system characteristics, and communication and electronic .warfare descriptions. These inputs are used to build the data structures and various lists comprising the initial dynamic storage array. The dynamic storage array is updated as the simulation progresses, and it provides an up-to-date status of the simulation at any point in time.

The execution phase is actually a series of runs to simulate each step of the war. Each run step begins with the loading of the dynamic storage array from the previous step and also the Red and Blue operations orders for this run. The actual simulation consists of the control routines invoking the various modules to execute continuous and discrete events. This execution produces a variety of outputs including running commentary on the major actions, status summaries of the various units, and any signal intelligence gained over this period of simulation. At the end of the run, the dynamic storage array is saved for the next step. The user then evaluates the output information and prepares operations orders for the next run step.

TRACE is currently running on a Cyber 176 computer under the NOS/BE 1.2 operating system. The simulation consists of approximately 450 FORTRAN subroutines requiring 50,000 60-bit words of small core memory (SCM) and between 30 to 65 thousand (depending on the scenario) 60-bit words of large core memory (LCM). The computer run time for a simulation is extremely dependent on the combat scenario. Test runs with a limited breakthrough scenario have required 30 to 40 CP seconds per hour of combat simulation time.

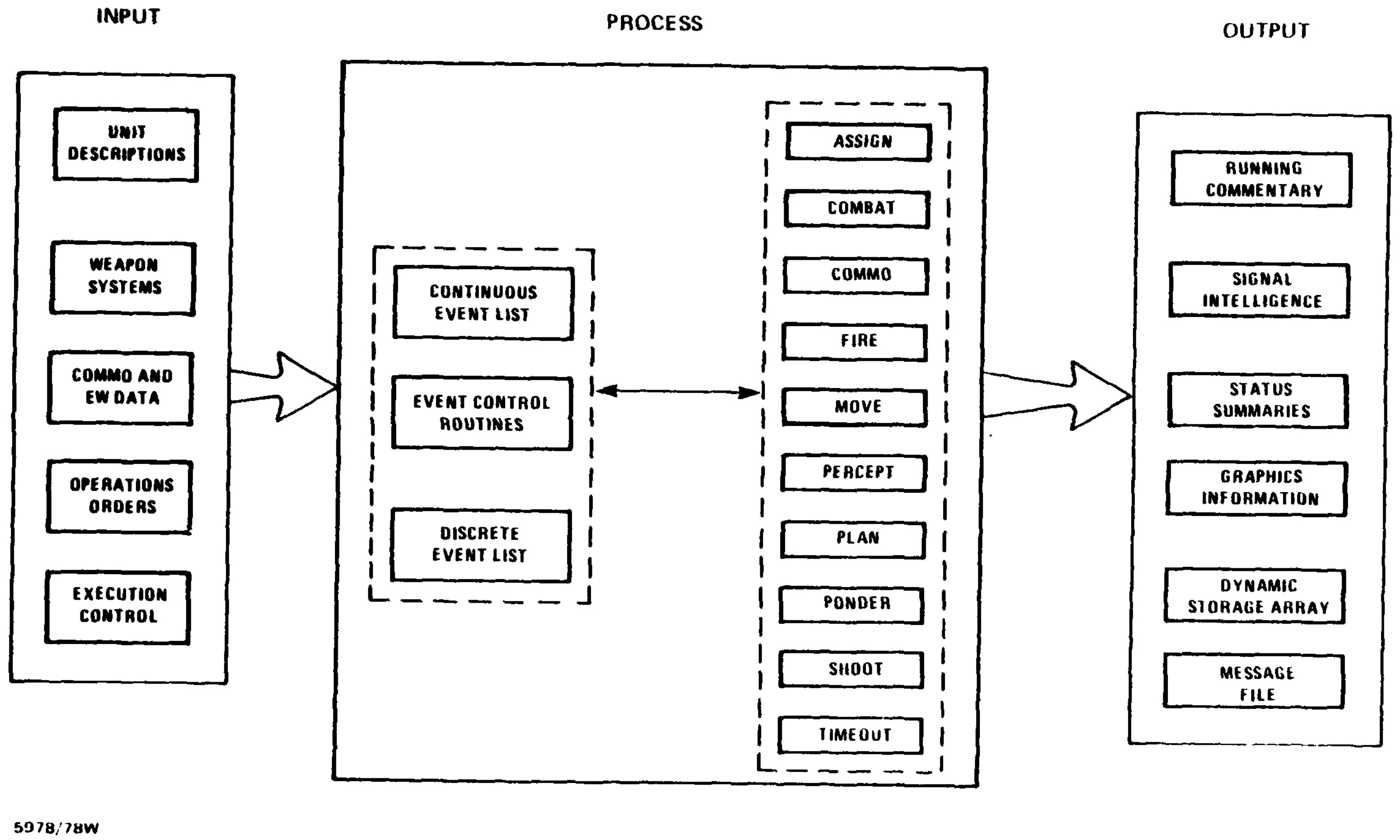

Figure 1. TRACE model overview.

SECTION 2
SIMULATION INPUT DESCRIPTION

2.1 INTRODUCTION

There are five basic types of user inputs to the TRACE simulation:

(1) Input sentences defining the combat scenario, i.e., the command and control relationships, unit locations, and force levels.

(2) Data base values defining the various weapon system characteristics such as firing rates and attrition probabilities.

(3) Communication and electronic warfare inputs describing unit and system capabilities in these areas.

(4) Operations orders for each simulation phase.

(5) User directives controlling the execution of TRACE.

The first three of these inputs are used only in the initialization phase of the simulation in order to define the scenario. These values (except for unit locations and force levels) remain fixed throughout the simulation. Thus, if the scenario is to be changed (e.g., an increase or decrease in the number of units, or an adjusted attrition probability), the initialization phase must be redone. The operations orders and user directives are input at the start of each execution phase of the simulation. The orders determine the basic combat plan for each side. The directives determine the available outputs, execution length, etc.

2.2 UNIT DESCRIPTIONS

The User Oriented Input Language (UOIL) has been developed for the METRIC Family to provide the user the capability to define inputs using English-like sentence descriptions of the units comprising the combat scenario. These sentences describe the command and control relationships among the various units as well as their location and equipment on hand. Figure 2 is an example of UOIL input for part of a NATO force. The following paragraphs briefly describe the various types of sentences used in the UOIL input.

```
NATO.
  US.
     5 CORPS COMMANDS 5 HHC.
         5 HHC IS AT HEX 777773277.
         5 HHC HAS 1 ATU, 40 ROUNDS.
     5 CORPS COMMANDS 3 ARMDIV.
         3 ARMDIV COMMANDS 3 HHC.
              3 HHC IS AT HEX 777772733
              3 HHC HAS 1 ATU, 40 ROUNDS.
         3 ARMDIV COMMANDS 2 ARMBDE.
              2 ARMBDE COMMANDS 20 HHC.
                  20 HHC IS AT HEX 777772246.
                  20 HHC HAS 1 ATU, 40 ROUNDS.
              2 ARMBDE COMMANDS 22 MECHBN.
                  22 MECHBN COMMANDS 220 HHC.
                      220 HHC IS AT HEX 777772671.
                      220 HHC HAS 1 ATU, 40 ROUNDS.
                  22 MECHBN COMMANDS 221 ARMCO.
                      221 ARMCO IS AT HEX 777772677.
                      221 ARMCO HAS 17 TANKS, 1 ATU, 1071 ROUNDS.
                  22 MECHBN COMMANDS 222 MECCO.
                      222 MECCO IS AT HEX 777772673.
                      222 MECCO HAS 13 ATU, 128 ROUNDS.
         3 ARMDIV COMMANDS 4 DIVARTY.
              4 DIVARTY COMMANDS 40 HHB.
                  40 HHB IS AT HEX 777772734.
                  40 HHB HAS 1 ATU, 40 ROUNDS.
              4 DIVARTY COMMANDS 41 ARTYBN.
                  41 ARTYBN COMMANDS 410 HHB.
                      410 HHB IS AT HEX 777772736.
                      410 HHB HAS 1 ATU, 40 ROUNDS.
                  41 ARTYBN COMMANDS 411 BTY175.
                      411 BTY175 IS AT HEX 777772274.
                      411 BTY175 HAS 1 ATU, 4 TUBES, 416 ROUNDS.
```

Figure 2. Example of user oriented input language (UOIL).

2.2.1 Side and Nationality Sentences

At the beginning of the input for the forces for either Red or Blue, a simple declaration of "WP" or "NATO", respectively, will signify that all units which follow will belong to that side, either until the end of the data, or until another side sentence is encountered. The nationality sentence works in the same manner. At the present time, the nationality sentence will not cause units of a different nationality on the same side to act according to different doctrine. For a list of acceptable side and nationality codes, see Appendix C.

2.2.2 Command and Control Sentence

This sentence describes who commands whom in the combat scenario and has the following form:

N1 "typeechelon" COMMANDS N2 "type-echelon".

N1 and N2 are the numerical designations of the respective units, while "type-echelon" specifies the type of unit. For example,

101 MECHDIV COMMANDS 2 ARMBDE.

"MECHDIV" is an abbreviation for Mechanized Division and "ARMBDE" stands for Armored Brigade. For a list of acceptable unit types see the grammatical definitions in Appehdix C.

2.2.3 Unit Location Sentence

The location sentence specifies the hex address where a unit is located at the beginning of the combat simulation. (For a description of hex addresses and the hexagonal coordinate system, see Appendix A.) This sentence is of the form:

N1 "type-echelon" IS AT HEX H1 .

H1 is the hex address where the unit is located. For example,

5 HHC IS AT HEX 777773277 .

Note that only company level units have input locations; all other echelons derive their aggregated location from the location of their subordinates. Because the hex address is an integer, at least one space must come between it and the period (.) following it.

2.2.4 Material Sentence

This sentence describes the ammunition and equipment a unit has on hand at the beginning of a simulation and is of the form:

N1 "type-echelon" HAS M1 "material type", M2 "material type", etc. M1 and M2 are the numbers of the specified material or equipment the unit currently possesses. For example,

221 ARMCO HAS 17 TANKS, 1 ATU, 1971 ROUNDS.

For a list of the permissible material types, see the grammatical definition of UOIL in Appendix C.

A type number may also be specified for each material type. The default of this is type 1. When another type is desired the sentence has the form:

N1 "type-echelon" HAS M1 "material type" OF TYPE N2

N2 is an integer number differentiating the type. For Example,

220 HHC HAS 1 ATU, 40 ROUNDS, 3 RADIOS OF TYPE 2 .

In this example only the radios are of type 2. The type phrase may be added to any "material type". At this time only radios are affected. Note the space before the period at the end of the example. This is because the type number is an integer.

2.3 WEAPON SYSTEM CHARACTERISTICS

The TCOR data base inputs to describe weapon system characteristics include five classes of data:

(1) Attrition factors;

(2) Maximum firing rates;

(3) Maximum firing ranges;

(4) Maximum movement rates; and,

(5) Maximum acquisition ranges.

The attrition rates, firing rates, and firing ranges are specified for infantry, armor, tube artillery, and rocket artillery. Movement rates, and acquisition ranges, in addition to being defined for units of these four classes, are also defined for headquarters companies or batteries. A separate set of input values is read for each side.

Figure 3 provides a short definition of each of these weapon characteristics, along with the variable names. Figure 4 displays the format order in which the variables are read (Blue first then Red). Figure 5 is an example of an input set which was used in a TRACE test scenario.

The following variables are attrition coefficients for weapons (conventional and nuclear). These coefficients are floating point numbers, between 0.0 and 1.0, and are used to tune the kill rate equations. They have no correspondence to a concise interpretation.

VARIABLE NAME		DEFINITION
CONV	NUCLEAR	
ACII	N/A	by infantry on infantry
ACIA	N/A	by infantry on armor
ACIT	N/A	by infantry on artillery tubes
ACIR	N/A	by infantry on rockets
ACIA	N/A	by armor on infantry
ACAA	N/A	by armor on armor
ACAT	N/A	by armor on artillery tubes
ACAR	N/A	by armor on rockets
ACTI	ANTI	by artillery tubes on infantry
ACTA	ANTA	by artillery tubes on armor
ACTT	ANTT	by artillery tubes on artillery tubes
ACTR	ANTR	by artillery tubes on rockets
ACRI	ANRI	by rockets on infantry
ACRA	ANRA	by rockets on armor
ACRT	ANRT	by rockets on artillery tubes
ACRR	ANRR	by rockets on rockets

The following variables are weapon characteristics for infantry, armor, artillery tubes, rocket, and headquarters units.

INF	ARMOR	TUBES	ROCKET	HQ	
MAXRI	MAXRA	MAXRT	MAXRR	N/A	maximum firing range in meters.
RATEI	RATEA	RATET	RATER	N/A	firing rates in rounds/weapon/unit-time*.
MOVEI	MOVEA	MOVET	MOVER	MOVEH	unit movement rates in centimeters/second.
LOOKI	LOOKA	LOOKT	LOOKR	LOOKH	maximum acquisition range in meters.

* arty: 128 seconds; non-arty: 64 seconds

Figure 3. Definitions of weapon system variables.

```
ACII,ACIA,ACIT,ACIR
ACAI,ACAA,ACAT,ACAR
ACTI,ACTA,ACTT,ACTR
ACRI,ACRA,ACRT,ACRR
ANTI,ANTA,ANTT,ANTR
ANRI,ANRA,ANRT,ANRR
MAXRI,MAXRA,MAXRT,MAXRR
RATEI,RATEA,RATET,RATER
MOVEI,MOVEA,MOVET,MOVER,MOVEH
LOOKI,LOOKA,LOOKT,LOOKR,LOOKH
```

1) 10 card images are read for each side, Blue first then Red.

2) Variables are read from the card images in the order shown above in free format.

3) Those variables beginning with the letter "A" or "R" are read as real numbers, while those beginning with "L" or "M" are read as integers.

Figure 4. Weapon systems input format.

INF	ARMOR	TUBE	ROCKET	HQ UNIT	
.0030,	.0026,	.0001,	.0001		BLUE
.0097,	.00165,	.0001,	.0001		ATTRITION
.0090,	.0090,	.0020,	.0001		FACTORS
.0,	.0,	.0,	.0		AGAINST RED
.44,	.35,	.9,	.49		BLUE NUCLEAR
.55,	.45,	.63,	.61		ATTRITION FACTORS
3000,	3000,	19200,	95000		BLUE FIRING RANGES (METERS)
.227,	.896,	3.86,	1.0		BLUE FIRING RATES (RNDS/MIN)
666,	666,	666,	666,	666	BLUE MOVE RATES (CM/SEC)
3000,	3000,	3000,	3000,	18000	BLUE ACQ RANGES (METERS)
.0058,	.0058,	.0001,	.0001		RED
.0058,	.0070,	.0001,	.0001		ATTRITION
.003,	.004,	.0011,	.0001		FACTORS
.0,	.0,	.0,	.0		AGAINST BLUE
.42,	.32,	.9,	.7		RED NUCLEAR
.59,	.48,	.75,	.32		ATTRITION FACTORS
3000,	2000,	18000,	75000		RED FIRING RANGES (METERS)
.214,	.568,	2.64,	1.0		RED FIRING RATES (RNDS/MIN)
666,	666,	666,	666,	666	RED MOVE RATES (CM/SEC)
3000,	3000,	3000,	3000,	18000	RED ACQ RANGES (METERS)

Figure 5. Example TRACE weapon system input.

In Figure 5, the test outside the dashed line does not occur on the input. It is provided for ease of reading only.

2.4 COMMUNICATION/ELECTRONIC WARFARE INPUTS

TRACE performs detailed simulation of communication networks and SIGINT, direction finding, and jamming efforts against message traffic over these networks. To perform this detailed communication simulation, the user must input:

a. Communication network characteristics;

b. Communication net members; and,

c. EW equipment characteristics.

2.4.1 Communication Network Characteristics

In order to define a communication network, the user must specify:

- Equipment/traffic characteristics of the net;
- Unit members of the network.

Figures 6 and 7 are examples of communication net inputs for the BLUE 3rd Division Command Net and 3rd Brigade Intelligence Net. Also, Figure 8 is the exact computer card format needed to define a communication net.

Twenty equipment/traffic characteristics are needed in the input definition of a net:

1. Side

   Indicates whose network is being defined. At this time only BLUE nets are modeled.

2. Net Type

   Indicates type of message traffic normally transmitted over the network. In TRACE, there are 5 possible network types:

   1 - Operations Command Net to handle operations orders from a commander to his subordinates.

   2 - Administrative Net for status reports from a subordinate to his commander.

   3 - Artillery Request Net for support requests from a unit to artillery battalions.

```
C*******************************************************************************
BLUE 3 DIV COMMAND NET
C*******************************************************************************
     1                       NET TYPE  1-OP/2-ADMIN/3-ARTY/4-INTELL/5-CAS
     6                       NET LEVEL          7-CORPS/6-DIV/5-BDE/4-BN
     1                       SECURITY MODE
     1                       TRANSMISSION MODE  1-VOICE/2-TTY/3-FAX
   920    CHANNELS           NUMBER OF CHANNELS
     5    STATIONS           NUMBER OF STATIONS IN NET
   65.05  MHZ                NET FREQUENCY
   75.95  MHZ                MAX FREQUENCY
   30.00  MHZ                MIN FREQUENCY
   40.00  %                  DUTY CYCLE
    5.0   %                  BACKGROUND TRAFFIC
    0.0   %                  CHANCE OF A SECURITY BREAK
   40.00  KM                 MAX EFFECTIVE COMMUNICATIONS DISTANCE
   35.00  KMH                COURIER SPEED
    2.0   MINUTES            AVERAGE MESSAGE LENGTH
    0.25  MINUTES            CONNECT TIME DELAY
   30.00  MINUTES            TIME AT WHICH TO USE COURIER
   15.00  MINUTES            TIME BEFORE USING ALTERNATE ROUTE
    5.00 MINUTES             TIME BEFORE USING ALTERNATE IF BEING JAMMED
  5 CORPS   3 DIV    0 BDE     0 BN      0 CO      52.0 %  DUTYCYCLE
  5 CORPS   3 DIV    1 BDE     0 BN      0 CO      12.0 %  DUTYCYCLE
  5 CORPS   3 DIV    2 BDE     0 BN      0 CO      12.0 %  DUTYCYCLE
  5 CORPS   3 DIV    3 BDE     0 BN      0 CO      12.0 %  DUTYCYCLE
  5 CORPS   3 DIV    4 BDE     0 BN      0 CO      12.0 %  DUTYCYCLE
```

Figure 6. Example communications input - command net.

```
C******************************************************************************
BLUE 3 BDE INTELL NET
C******************************************************************************
     4                      NET TYPE  1-OP/2-ADMIN/3-ARTY/4-INTELL/5-CAS
     5                      NET LEVEL         7-CORPS/6-DIV/5-BDE/4-BN
     1                      SECURITY MODE
     1                      TRANSMISSION MODE  1-VOICE/2-TTY/3-FAX
   920     CHANNELS         NUMBER OF CHANNELS
     6     STATIONS         NUMBER OF STATIONS IN NET
  72.85   MHZ               NET FREQUENCY
  75.95   MHZ               MAX FREQUENCY
  30.00   MHZ               MIN FREQUENCY
  18.00   %                 DUTY CYCLE
   5.0    %                 BACKGROUND TRAFFIC
   0.0    %                 CHANCE OF A SECURITY BREAK
  40.00   KM                MAX EFFECTIVE COMMUNICATIONS DISTANCE
  30.00   KMH               COURIER SPEED
   2.3    MINUTES           AVERAGE MESSAGE LENGTH
   0.10   MINUTES           CONNECT TIME DELAY
  20.00   MINUTES           TIME AT WHICH TO USE COURIER
  10.00   MINUTES           TIME BEFORE USING ALTERNATE ROUTE
   1.00 MINUTES             TIME BEFORE USING ALTERNATE IF BEING JAMMED
 5 CORPS   3 DIV     3 BDE     0 BN      0 CO      50.0 %  DUTYCYCLE
 5 CORPS   3 DIV     3 BDE    31 BN      0 CO      10.0 %  DUTYCYCLE
 5 CORPS   3 DIV     3 BDE    32 BN      0 CO      10.0 %  DUTYCYCLE
 5 CORPS   3 DIV     3 BDE    33 BN      0 CO      10.0 %  DUTYCYCLE
 5 CORPS   3 DIV     3 BDE    34 BN      0 CO      10.0 %  DUTYCYCLE
 5 CORPS   3 DIV     3 BDE    35 BN      0 CO      10.0 %  DUTYCYCLE
```

Figure 7. Example communications input - intelligence net.

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```
         1111111111222222222233333333334444444444555555555566666666667777777777888
1234567890123456789012345678901234567890123456789012345678901234567890123456789 0
 1 C•••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
 2 XXXX NAME OF COMMUNICATIONS NET
 3 C•••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••••
 4 XXXXXX                   NET TYPE            1-OP/2-ADMIN/3-ARTY/4-INTELL/5-CAS
 5 XXXXXX                   NET LEVEL           7-CORPS/6-DIV/5-BDE/4-BN
 6 XXXXXX                   SECURITY MODE       1-CONSTANT
 7 XXXXXX                   TRANSMISSION MODE   1-VOICE/2-TTY/3-FAX
 8 XXXXXX    CHANNELS       NUMBER OF CHANNELS
 9 XXXXXX    STATIONS       NUMBER OF STATIONS IN NET
10 XXXXX.XXX MHZ            NET FREQUENCY
11 XXXXX.XXX MHZ            MAX FREQUENCY
12 XXXXX.XXX MHZ            MIN FREQUENCY
13 XXXXX.XXX %              DUTY CYCLE
14 XXXXX.XXX %              BACKGROUND TRAFFIC
15 XXXXX.XXX %              CHANCE OF A SECURITY BREAK
16 XXXXX.XXX KM             MAX EFFECTIVE COMMUNICATIONS DISTANCE
17 XXXXX.XXX KMH            COURIER SPEED
18 XXXXX.XXX MINUTES        AVERAGE MESSAGE LENGTH
19 XXXXX.XXX MINUTES        CONNECT TIME DELAY
20 XXXXX.XXX MINUTES        TIME AT WHICH TO USE COURIER
21 XXXXX.XXX MINUTES        TIME BEFORE USING ALTERNATE ROUTE
22 XXXXX.XXX MINUTES        TIME BEFORE USING ALTERNATE IF BEING JAMMED
23 XXX CORPS XXX DIV   XXX BDE   XXX BN    XXX CO    XXXX X %  DUTY CYCLE
24
25
```

NOTE: COMPUTER READS ONLY THOSE FIELDS MARKED WITH Xs, ALL OTHER DATA IS IGNORED, BUT IS USEFUL FOR DOCUMENTATION PURPOSES.

LINES 1 & 3	:	ARE SKIPPED
LINE 2	:	READS EITHER "BLUE" OR "RED" IN COLUMNS 1-4
LINES 4-9	:	LAST DIGIT OF THE INTEGER SHOULD BE IN COLUMN 6 (CARD READ IN I6 FORMAT)
LINES 10-22	:	DECIMAL POINT SHOULD BE IN COLUMN 6 (CARD READ IN F9.3 FORMAT)
LINE 23	:	- SHOULD BE REPEATED AS MANY TIMES AS SPECIFIED BY THE NUMBER IN LINE 8 - EACH UNIT NUMBER SHOULD BE RIGHT-JUSTIFIED IN ITS INPUT FIELD (CARD READ IN 5 (I3, 7X) FORMAT)

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Figure 8. Input format for defining a communications network.

4 - Intelligence Net for intelligence reports from a subordinate to his commander.

5 - Close Air Support Net for support requests from units to the corps air base.

3. <u>Net Level</u>

Indicates echelon of net control station: Corps (7); Division (6); Brigade (5); Battalion (4).

4. <u>Security Mode</u>

This field is reserved for use with a capability that is under development. For present purposes always input a 1 (one) signifying clear transmissions.

5. <u>Transmission Mode</u>

Indicates manner in which messages are transmitted over this network: voice transmissions (1); teletype transmissions (2); and facsimile transmissions (3).

6. <u>Number of Channels</u>

Indicates number of discrete channels available on communication equipment for this net. (Not used in TRACE versions of TCOR.)

7. <u>Number of Stations in Net</u>

Indicates total number of units which are members of this net. This number should exactly match the number of units listed after the net characteristics.

8. <u>Net Frequency</u>

Indicates frequency (in megahertz) at which messages are transmitted over this net.

9. <u>Max Frequency</u>

Indicates highest frequency at which net communication equipment can transmit.

10. <u>Min Frequency</u>

Indicates lowest frequency at which net communication equipment can transmit.

11. Duty Cycle

Included for future development. User should input 0.0 or any other legitimate percentage.

12. Background Traffic

Indicates percentage of time which net is transmitting background traffic. Net will be considered busy this percentage of time.

13. Chance of a Security Break on this Net

This field is reserved for use with a future capability. At present always input 0.0.

14. Max Effective Communication Distance Expected

Indicates maximum distance (in kilometers) at which the net communication equipment can be effective.

15. Courier Speed

Indicates speed (in kilometers/hour) at which couriers for the units in this net can deliver messages that cannot get through by electrical means.

16. Average Message Length

Indicates average time (in minutes) of transmission for type of traffic normally transmitted over this net.

17. Connect Time Delay

Included for future development. User should input "0.0".

18. Time at Which to Use Courier

Indicates average amount of time (in minutes) a unit will spend trying to get a message through on this net before sending the message by courier.

19. Time Before Using Alternate Route

Indicates average amount of time (in minutes) a unit will spend trying to send a message over this net before trying an alternate net.

20. Time Before Using Alternate Route When this Net Jammed

Indicates average amount of time (in minutes) a unit requires to determine that this net is jammed beyond effective use.

2.4.2 Communication Net Members

In order to define a communication net, the user must also specify all members of the net. This is done by listing all units in the net immediately after the net characteristics. In order to avoid ambiguity, units are identified using a required input format:

XXX CORPS XXX DIV XXX BDE XX BN XXX CO XXXXX.X % DUTYCYCLE

The unit's designation number together with the designation number for each commander in his chain of command must be listed. (The duty cycle entry will be explained later.) Note that a number must be input at each command level, corps through company. If there is no commander in the unit's chain at a certain level, then a 0 should be input. Consider the following examples:

- 30th Headquarters Company of the 3rd Division

5 CORPS 3 DIV 0 BDE 0 BN 30 CO

The unit number of this company is 30; it reports directly to the 3rd Division, so there are no battalions or brigades in his chain of command; the only corps in this scenario is the 5 Corps.

- 3rd Division

5 CORPS 3 DIV 0 BDE 0 BN 0 CO

This is a division level unit; hence, there are no companies, battalions, or brigades in the chain of command.

- 2nd Brigade of the 3rd Division

5 CORPS 3 DIV 2 BDE 0 BN 0 CO

Note that there is an inherent scenario limitation in this numbering system: subordinates (at the same echelon level) of the same commander must have unique unit designation numbers; e.g., there cannot be a 3rd Armored Division and a 3rd Infantry Division both commanded by the 5th Corps.

For this simulation, companies do not send actual messages. Hence, net members must be battalion level or higher. However, the actual physical location of a unit's communication equipment is at the unit's headquarters company. When specifying members of a network with this input format, the unit which is net control station should be the first unit in the list, and there should be an input line for each net member. In addition to the designation numbers for a unit, there must also be an input entry for the unit's net duty cycle. This number represents the percentage of total net transmission which this unit is transmitting. This number is included for future development, and is not used at present; hence, any legitimate percentage is permissible. Figure 6 is an example of the input format used to specify a communication net. This net is composed of the 3rd Division (net control station) and the 1st, 2nd, 3rd, and 4th Brigades.

2.4.3 EW Equipment

TRACE simulates 3 types of EW equipment:

- Jamming Equipment;
- Intercept/Listening Equipment;
- Radio Direction Finding Equipment.

In order to input an item of EW equipment, the user must specify the characteristics of each separate piece of equipment along with a list of those Red units having this type of equipment. The same input format is used for all types of equipment. See Figure 12 for an example of the required input format. Figures 9, 10, and 11 illustrate Red EW data input. Twelve equipment characteristics are needed for input definition:

1. Side

   Indicates whose equipment is being defined. At this time only Red equipment is modeled.

2. Type Equipment

   Specifies equipment type described by these input characteristics. Input codes used are:

   1 - Jamming Equipment; 2 - Intercept Equipment; 3 - DF Equipment.

3. Number of Scanners

   Applies only to intercept equipment (0 should be used for DF and Jamming Equipment). Represents number of discrete frequencies an intercept unit can listen to simultaneously. (NOTE: This parameter allows user to group intercept equipment of the same type.)

```
C******************************************************************************
RED VHF JAMMER
C******************************************************************************
     1    TYPE          TYPE EQUIPMENT 1-JAM,2-LISTEN,3-DF
     0    SCANNERS      NUMBER OF SCANNERS
     0    NETS          NUMBER OF PRIMARY NETS TARGETED AGAINST
     0    POLICY        EW POLICY FOR THIS EQUIPMENT
     2    UNITS         NUMBER OF UNITS WITH THIS TYPE EQUIPMENT
   25.    KM            MAXIMUM EFFECTIVE DISTANCE
   75.95  MHZ           MAXIMUM FREQUENCY
   30.05  MHZ           MINIMUM FREQUENCY
    5.00  MHZ           BANDWIDTH
    0.0   SECONDS       MINIMUM TIME TO SCAN/DF A SIGNAL
    0.0   SECONDS       SCAN TIME PER CHANNEL
  1 TA      9 DIV     8 REG    81 BN    814 CO
  1 TA      9 DIV     8 REG    81 BN    815 CO
```

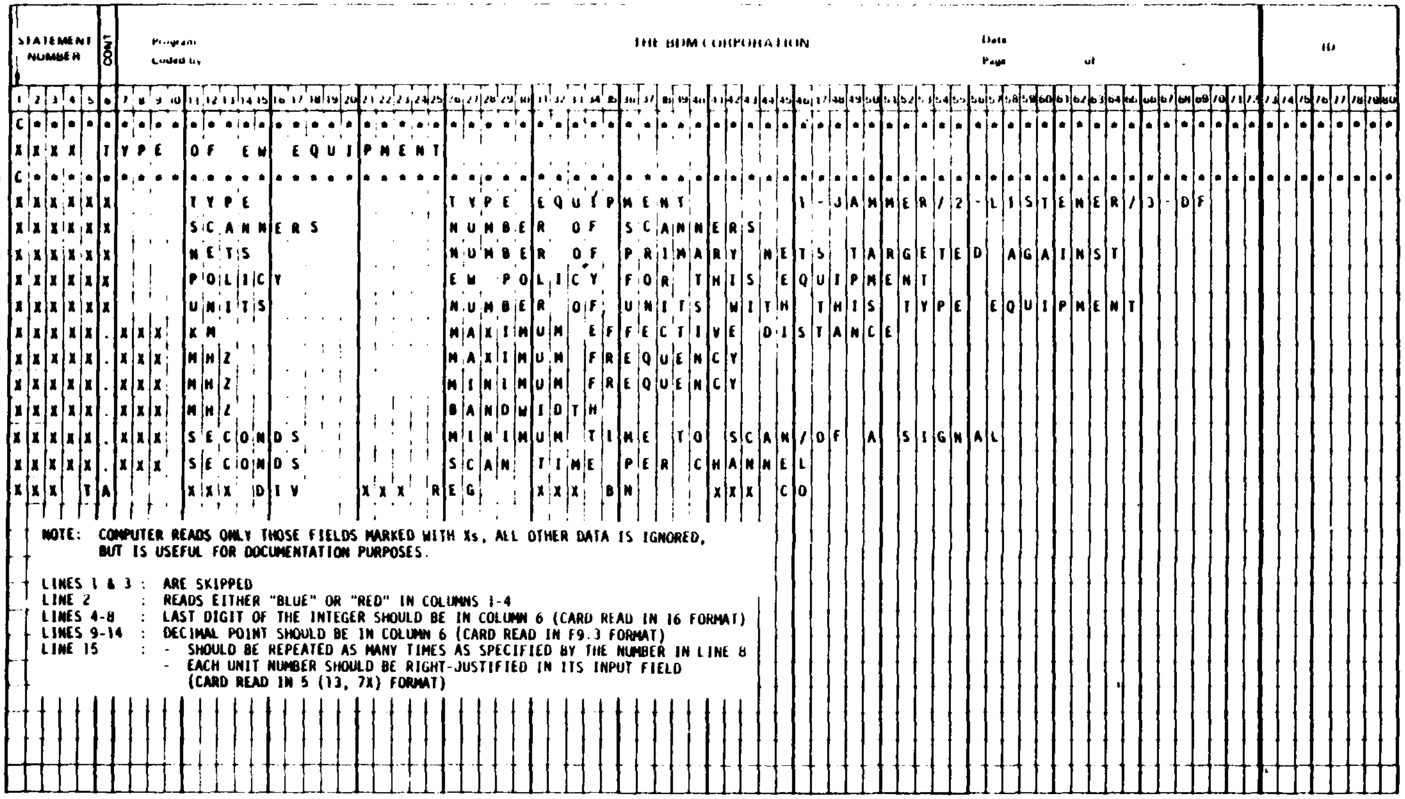
Figure 9. Example EW input - jammer.

```
C*******************************************************************************
RED HF LISTENER
C*******************************************************************************
     2    TYPE           TYPE EQUIPMENT 1-JAM,2-LISTEN,3-DF
    10    SCANNERS       NUMBER OF SCANNERS
     0    NETS           NUMBER OF PRIMARY NETS TARGETED AGAINST
     0    POLICY         EW POLICY FOR THIS EQUIPMENT
     1    UNITS          NUMBER OF UNITS WITH THIS TYPE EQUIPMENT
 700.0    KM             MAXIMUM EFFECTIVE DISTANCE
  30.0    MHZ            MAXIMUM FREQUENCY
   2.0    MHZ            MINIMUM FREQUENCY
   0.0    MHZ            BANDWIDTH
  45.0    SECONDS        MINIMUM TIME TO SCAN/DF A SIGNAL
   0.5    SECONDS        SCAN TIME PER CHANNEL
 1 TA       9 DIV     8 REG    82 BN    820 CO
```

Figure 10. Example EW input - listener.

```
C********************************************************************************
RED VHF DF
C********************************************************************************
     3     TYPE            TYPE EQUIPMENT 1-JAM,2-LISTEN,3-DF
     0     SCANNERS        NUMBER OF SCANNERS
     0     NETS            NUMBER OF PRIMARY NETS TARGETED AGAINST
     0     POLICY          EW POLICY FOR THIS EQUIPMENT
     3     UNITS           NUMBER OF UNITS WITH THIS TYPE EQUIPMENT
  25.0     KM              MAXIMUM EFFECTIVE DISTANCE
  75.95    MHZ             MAXIMUM FREQUENCY
  30.05    MHZ             MINIMUM FREQUENCY
   0.0     MHZ             BANDWIDTH
  30.0     SECONDS         MINIMUM TIME TO SCAN/DF A SIGNAL
   0.0     SECONDS         SCAN TIME PER CHANNEL
 1 TA        9 DIV     8 REG     81 BN    811 CO
 1 TA        9 DIV     8 REG     81 BN    812 CO
 1 TA        9 DIV     8 REG     81 BN    813 CO
```

Figure 11. Example EW input - DF.



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```
1  C...............................................................................
2  XXXX TYPE OF EW EQUIPMENT
3  C...............................................................................
4  XXXXXX    TYPE           TYPE EQUIPMENT      1-JAMMER/2-LISTENER/3-DF
5  XXXXXX    SCANNERS       NUMBER OF SCANNERS
6  XXXXXX    NETS           NUMBER OF PRIMARY NETS TARGETED AGAINST
7  XXXXXX    POLICY         EW POLICY FOR THIS EQUIPMENT
8  XXXXXX    UNITS          NUMBER OF UNITS WITH THIS TYPE EQUIPMENT
9  XXXXX.XXX KM             MAXIMUM EFFECTIVE DISTANCE
10 XXXXX.XXX MHZ            MAXIMUM FREQUENCY
11 XXXXX.XXX MHZ            MINIMUM FREQUENCY
12 XXXXX.XXX MHZ            BANDWIDTH
13 XXXXX.XXX SECONDS        MINIMUM TIME TO SCAN/OF A SIGNAL
14 XXXXX.XXX SECONDS        SCAN TIME PER CHANNEL
15 XXX TA    XXX DIV   XXX REG   XXX BN    XXX CO
16
17
18
19
20
21
22
23
24
25
```

NOTE: COMPUTER READS ONLY THOSE FIELDS MARKED WITH Xs, ALL OTHER DATA IS IGNORED, BUT IS USEFUL FOR DOCUMENTATION PURPOSES.

```
LINES 1 & 3 :  ARE SKIPPED
LINE 2      :  READS EITHER "BLUE" OR "RED" IN COLUMNS 1-4
LINES 4-8   :  LAST DIGIT OF THE INTEGER SHOULD BE IN COLUMN 6 (CARD READ IN 16 FORMAT)
LINES 9-14  :  DECIMAL POINT SHOULD BE IN COLUMN 6 (CARD READ IN F9.3 FORMAT)
LINE 15     :  -  SHOULD BE REPEATED AS MANY TIMES AS SPECIFIED BY THE NUMBER IN LINE 8
               -  EACH UNIT NUMBER SHOULD BE RIGHT-JUSTIFIED IN ITS INPUT FIELD
                  (CARD READ IN 5 (13, 7X) FORMAT)
```

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Figure 12. Input format to specify EW equipment.

4. Number of Primary Nets Targeted

Included for future development; user should input 0.

5. EW Policy for this Equipment

Included for future development; user should input 0.

6. Number of Units with This Type of Equipment

Indicates total number of this type equipment possessed by Red EW units. This number should exactly match the number of units listed after the equipment characteristics. (NOTE: If a unit possesses more than one piece of this equipment, it should be included in the input list a corresponding number of times.) Each piece of equipment is assumed to be collocated with the unit to which it belongs.

7. Maximum Effective Distance

Indicates maximum distance (in kilometers) at which equipment is effective.

8. Maximum Frequency

Indicates the highest frequency (in megahertz) at which this equipment can operate effectively.

9. Minimum Frequency

Indicates the lowest frequency (in megahertz) at which this equipment can operate effectively.

10. Jamming Bandwidth

Indicates the bandwidth (in megahertz) that a jammer covers. It is zero for DF and intercept equipment.

11. Minimum Time to Scan/DF

Used for intercept and DF equipment only. For intercept equipment, it is the average time (in seconds) required to determine that a signal on a specific channel is of interest (assuming that it has already been determined that a signal is being transmitted on this channel). For DF equipment, it indicates the average time (in seconds) required to obtain a bearing on a signal once the signal frequency has been determined.

12. Scan Time Per Channel

Used for intercept and DF equipment only. Time (in seconds) required for this equipment to move from one channel to the next.

Immediately after the equipment characteristics there should be a list of the unit locations of this piece of equipment. The same input code format as explained earlier for communication net members should be used. However, for EW equipment, the units should all be company size. This equipment will be located at the same physical location as the unit. The echelon names of the input format have been changed to tank army, division, regiment, battalion, and company in order to be consistent with RED Army terminology as used in the examples:

XXX TA XXX DIV XXX REG XXX BN XXX CO

For example, suppose there is only one HF listener which is collocated with the 820th Company of the 82nd Battalion. Then, its unit input line after the equipment characteristics would be:

1 TA 9 DIV 8 REG 82 BN 820 CO

At this time, only RED companies 810-815 and 820-825 may have EW equipment.

2.5 OPERATIONS ORDER INPUTS

A TRACE simulation is actually a series of simulations interspersed with operations orders input by the man-in-the-loop (MITL). At the beginning of each simulation run, the user specifies the amount of combat time he wants to simulate and also the operations orders for the higher level command units of both Red and Blue. These higher level units interpret the orders, plan accordingly, and issue appropriate orders to their subordinates. Thus, the user supplies orders only at the highest command level, and the orders for lower level units are generated automatically.

The operations orders input for TRACE was designed for interactive use by the MITL. However, this input is currently done in batch mode for the AFWL computer. The user supplies an input deck of cards, each of which is the appropriate answer to an interactive prompt. The user should use caution when submitting orders in this batch mode. Since the program attempts to validate most of the responses, it is extremely important to carefully check all cards in the input deck. If there is an invalid input card, the processor assumes the next card is the corrected response. Therefore, be sure all answers to the questions are correct and conform to the input described below.

The following is a description of the interactive method for inputting operations orders. To input in the batch mode, the user should supply the answers in the proper sequence. (For an example of this batch mode input, see Figure 13.)

OPORD and Jamming Orders Inputs

The following is an example of a MITL interactive session with the appropriate prompts, instructions, and replies that would normally be provided. Processor questions and instructions given below are underlined and numbered. Additional information regarding some of the questions has been provided (enclosed in double quotation marks) when necessary for those items that are not fully self-explanatory. After each instruction/question, respond by entering the information requested after the "?" and hitting the carriage return.

All times are expressed as DAY-HOUR-HOUR-MINUTE-MINUTE. The run represents the first execution run from time 10000 to 10800 (480 minutes) with the actual action of the simulation to start at dawn of the first day. The Blue Fourth Artillery Brigade is being transfered from the Fourth Division to the Third Division. The Third Division for Blue is given orders to engage in a defend operation from 10600 to 10830. The extra thirty minutes that the operations order is to be in effect allows for the time lapse of the next set of orders on the following run (from 10800 to 11000) as they are being sent to the lower echelons. No nuclear weapons are permitted. The Third Division is given one phaseline and told to defend using a screen/move operation. Red has been told to turn on jammers for Unit 814 for one hour at 56.250 megahertz beginning at 10700.

The following represents what the user will see as he corresponds with the processor via an input/output terminal:

```
 (1) ENTER TIME POINT TO HOOK ORDERS TO (ENTER TIME IN SECONDS)
     "Because the OPORD processing will, at times, need to know where
     a unit's data is stored in memory; it must operate on the parti-
     cular checkpoint that will be used for execution."
 ?  0
 (2) ENTER LEVEL FOR INSTRUCTION (FULL/PARTIAL)
 ?   FULL
 (3) ENTER LENGTH OF NEXT RUN (MINUTES)
 ?   480
 (4) WHICH SIDE (RED/BLUE/NONE) FOR NUCLEAR STRIKE
 ?   RED
 (5) ENTER GAME TIME OF BURST (TDGZ) IN SECONDS
 ?   7200
 (6) ENTER TEN TIMES THE YIELD IN KILOTONS (INTEGER)
 ?   200
 (7) ENTER TARGET HEX
 ?   777772635
 (8) REVIEWING WHAT YOU HAVE ENTERED
       20.0KT BURST SET OFF IN HEX 777772635 AT 7200 SECONDS INTO THE GAME
       IS IT ACCEPTABLE (YES/NO)
 ?   YES
 (9) WHICH SIDE (RED/BLUE/NONE) FOR NUCLEAR STRIKE
 ?   NONE
(10) WHICH SIDE (RED/BLUE/NONE) "For reassignment/reorganization orders."
 ?   BLUE
(11) ENTER UNIT TO BE MOVED
     INPUT UNIT DESIGNATION:
     CORPS/CAA, DIV, BDE/REG, BN
     WITH ZERO (0) WHERE NO UNIT AT THAT ECHELON
     "5 Corps 4 Division 4 Brigade."
 ?   5, 4, 4, 0
```

```
(12) ENTER OLD COMMANDER
     INPUT UNIT DESIGNATION:
     CORPS/CAA, DIU, BDE/REG, BN
     WITH ZERO (0) WHERE NO UNIT AT THAT ECHELON
 ?   5, 4, 0, 0
(13) ENTER NEW COMMANDER
     INPUT UNIT DESIGNATION:
     CORPS/CAA, DIV, BDE/REG, BN
     WITH ZERO (0) WHERE NO UNIT AT THAT ECHELON
 ?   5, 3, 0, 0
(14) ENTER EFFECTIVE TIME (IN SECONDS) OF GAME  "After one hour."
 ?   3600
(15) REVIEWING WHAT YOU HAVE ENTERED
     DO YOU WANT TO USE THIS REASSIGNMENT (YES/NO)
 ?   YES
(16) WHICH SIDE (RED/BLUE/NONE) "For reassignment"
 ?   NONE "To end reassignments."
(17) WHICH SIDE (RED/BLUE/NONE) "For Operations Orders"
 ?   BLUE
(18) INPUT UNIT DESIGNATION
     CORPS/CAA,DIV,BDE/REG,BN
     WITH ZERO (0) WHERE NO UNIT AT THAT ECHELON
     "Ex. for 5 Corps, 3 Division"
 ?   5,3,0,0
(19) INPUT OPERATION (ATK/DEF)
     "Attack or defend - overall operation type for this unit and subordinates
     for the duration of this OPORD"
 ?   DEF
(20) INPUT INITIAL, FINAL TIMES AS INTEGER DHHMM
     "Enter the initial and end time for the effect of this order.  Always
     let the effective times extend 30-45 minutes past the end of the next
     run.  This allows the old order to be used at the start of each run
     while the new one is being processed and sent to the lower echelon
     units."  "Ex.  If the order is to be in effect from 10600 to the end
     of the run, then allow it to be in effect from 10600 to 10830."
 ?   10600, 10830
(21) INPUT GS PRIORITY AS INTEGER PERCENT
     "Enter percent of artillery to be used for general support."
 ?   50
(22) ARE NUCLEAR WEAPONS PERMITTED
 ?   NO "or YES as the case may be"
(23) INPUT ACCEPTABLE CASUALTY LIMIT, AND MIN SUPPLY LEVEL AS INTEGER PERCENTS
 ?   20,30
(24) INPUT MIN, MAX SPEED LIMITS AS INTEGER PERCENT OF UNIT THEORETICAL BEST
     SPEED "Ex.  For move between 20 and 70 percent of theoretical max"
 ?   20,70
(25) INPUT LEFT BOUNDARY HEXES (AS FACE DIRECTION OF MOVEMENT)
     REAR TO FRONT, FOLLOWED BY ZERO (0) THEN RIGHT BOUNDARY HEXES -- REAR
     TO FRONT.
     TERMINATE LIST BY A NINE (9).
     "NOTE:  Each side of the boundary must have at least 3 coordinates
     since the phaseline will have to terminate at an interior boundary
     point on each side."
     "NOTE:  If any member of the list is not a valid hex number, you will
     be asked to replace the incorrect hex."
 ?   777776217, 777772417,777772524, 777772517, 0
 ?   777771734, 777772272, 777772212, 777772371, 9
(26) DO YOU NEED INSTRUCTIONS FOR INPUT OF PHASELINES (YES/NO)
 ?   YES
     YOU WILL BE ASKED TO INPUT AN OPERATION TYPE NUMBER FOR EACH PHASE.
     THE CODES REFER TO THE FOLLOWING:
     CODE              ATTACK            DEFEND
      1                MOVE TO CONTACT   HOLD POSITION
      2                BRKTHRU           DELAY
      3                HOLDING ATK       SCREEN MOVE
      4                EXPLOIT           COUNTERATTACK
      5                RESERVE           RESERVE
```

"NOTE: At present, use only 1 or 2 for attack, 3 for defend.

"Also, input the time for the end of the effect of this particular phaseline. Several phaselines may be used in one run, but if only one is input, then the end time should also extend past the end of the run by 30-45 minutes."

FOR THE PHASELINES, INPUT THE HEXES FROM LEFT TO RIGHT, MAKING SURE TO INCLUDE A HEX FROM THE LEFT AND RIGHT BOUNDARIES. TO TERMINATE HEXES, TYPE IN 9.

(27) INPUT OPERATION CODE (0 TO TERMINATE), AS INTEGER, END TIME OF PHASE AS INTEGER DHHMM

"Ex. For defend and until the end of the effect of this order:"

? 3, 10830

(28) INPUT HEX LIST AS INTEGERS

"If the first hex coordinate in the list is not on the left boundary, or if the last hex coordinate is not on the right boundary, then you will be asked to replace the incorrect coordinate with values that are on the corresponding boundaries defined in (10)."

? 77777772417, 77777772272, 9

(29) INPUT OPERATION CODE (0 TO TERMINATE), AS INTEGER, END TIME OF PHASE AS INTEGER DHHMM

"Repeat this input plus the hex list (steps 12 and 13) for each phase line. Enter 0, 0 if no more phase lines."

? 0,0

"At this time the processor will output the OPORD for the unit. At the end, you will be asked if you want to use it. If not, then say NO. You may then re-input the OPORD or go on to another unit's OPORD."

END OF PHASE INPUT FOR THIS UNIT "OPORD result now follows."

(30) DO YOU WANT TO USE THE LAST OPORD (YES/NO)

? YES

(31) WHICH SIDE (RED/BLUE/NONE)

"Do for both Red and Blue sides. Enter none when finished with OPORDS."

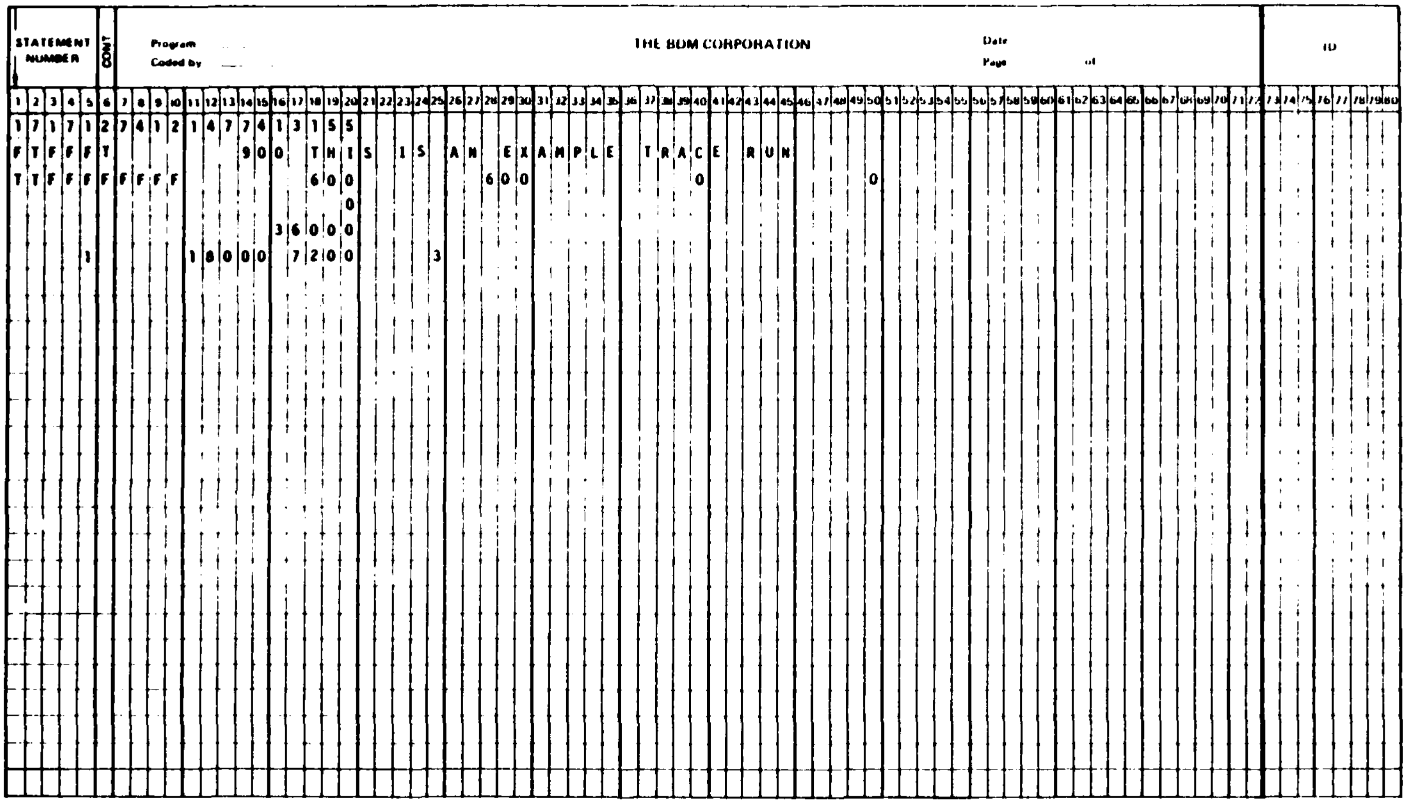
? NONE

```
(32) ENTER SIDE FOR JAMMING SUPPORT (RED/BLUE/NONE)
?    RED
(33) ENTER JAMMING COMPANY (0,814,815,824,825 ONLY)
?    814
(34) ENTER FREQUENCY (MHZ), START TIME (DHHMM), DURATION OF JAMMING MISSION
     (MINUTES)
?    56.250,10700,60
     "The processor will show the jamming order and ask for a new one"
(35) ENTER JAMMING COMPANY
     (0,814,815,824,825)
?    0
     "When all jamming orders are input, you will be asked if you want to
     use them".
(36) DO YOU WANT TO USE THESE JAMMING ORDERS (YES/NO)
?    YES
(37) ENTER SIDE FOR JAMMING SUPPORT
     (RED/BLUE/NONE)
?    NONE
```

2.6 USER DIRECTIVES

During each execution the user may specify a certain desired set of outputs to be generated by the model. Some of these outputs are files to be used or displayed later and others are information displayed during execution. The user must also control the behavior of the execution. Figure 13 shows a sample set of user directives. Associated with each time in the figure is a number. These numbers are used in the following to explain the use of each entry:

Line 1	Column 1-20	This is the seed for the random number generator. It is an integer in base 8. If 0 is used, the seed stored on the checkpoint file will be used.
Line 2	Column 1-6	These are logical flags.
	Column 1	Not used, enter F.
	Column 2	Use T if there are any OPORDs from the MITL. Use F if none.



STATEMENT NUMBER | CONT | Program | Coded by | THE BDM CORPORATION | Date | Page of | ID

```
17171274121477413155
FTFFFT       900 THIS IS AN EXAMPLE TRACE RUN
TTFFFFFFFF       600       600         0         0
                   0
               36000
    1     18000 7200    3
```

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Figure 13. Example set of user directives.

Column 3-5 Not used, enter F.

Column 6 Use T if a file is to be generated for the post processor. Use F if none is desired.

Column 7-16 This is an integer called, in the model, INCR. It is the time increment, in seconds, between data points on the post processor file if one is being generated.

Column 17-56 This is 40 characters of text giving a title to this instance of the execution.

Line 3 Column 1-10 These are logical flags.

Column 1 This is T if there is to be a maximum message transmission time for Blue messages. It is F otherwise.

Column 2 This is the same as column 1 only for Red messages.

Column 3 This is T if the Blue message transmission time is to be constant. It is F otherwise. If both column 1 and 3 are T then column 3 takes procedence.

Column 4 This is the same as column 3 but for Red messages.

Column 5-10 Not used, enter F.

Column 11-20 Given that column 1 is T this is the integer, maximum transmission time for Blue.

Column 2130 Given that column 2 is T, this is the maximum transmission time for Red.

Column 31-40 Given that column 3 is T, this is the transmission time for Blue.

Column 41-50 Given that column 4 is T, this is the transmission time for Red.

Line 4 Column 1-20 This is the integer time, in seconds, of the checkpoint used to initialize the execution. This time point must appear on the ISPACE file or the program stops.

Line 5 Column 1-20 This is the integer time, in seconds, that the simulations runs (game time, not real time).

Line 6 Line 6 is actually an example of one of a series of entries. Lines 1-5 must occur and in that order. There may be zero or more line 6 entries following those 5.

Column 1-5 This is an integer specifying the chosen output type.

1 = a status report display of unit status for both sides.

3 = a checkpoint is written to the ISPACE file.

4 = code 3 plus the model stops

Column 6-15 This is the wait time, in seconds, until the first of the output type is generated. It is an integer.

Column 16-20 This is the duration, in seconds, between successive outputs of this types. It is an integer.

Column 25 This is an integer and is the level of the lowest unit to be displayed. It is only applicable to output type 1. (See Appendix A for discussion of levels).

SECTION 3
RUNNING THE SIMULATION (JOB CONTROL LANGUAGE)

3.1 INTRODUCTION

This chapter provides a detailed, step-by-step explanation of the Job Control Language (JCL) necessary to run the TRACE simulation on the CDC Cyber 176 computer at the Air Force Weapons Laboratory (AFWL). The two AFWL Cyber 176 computers use the NOS/BE 1.2 operating system. The JCL explained in this chapter applies specifically to this operating system.

A TRACE combat simulation consists of four phases, initialization, MITL, execution, and post processing. Section 3.2 describes the JCL necessary for initializing the combat scenario, section 3.3 describes the MITL JCL and section 3.4 describes the actual simulation execution process. Section 3.5 describes the post processor.

3.2 SCENARIO INITIALIZATION

The first step of a TRACE simulation is to build the initial ISPACE for the desired scenario. The term "ISPACE" refers to the dynamic storage array used to hold the data structures and list structures needed for the simulation. This initial phase reads in the various user inputs describing the combat scenario and builds the necessary data structures and lists. (See Section 2 for a description of these inputs).

Figure 14 lists the JCL to run this initialization process while Figure 15 depicts this process. The remainder of this section provides a detailed explanation of each of these JCL steps.

JCL EXPLANATION (INITIALIZE SCENARIO)

JOB CARD.

ACCOUNT CARD.

The job and account card formats for the AFWL computer system are described in AFWL's system bulletins (SYSBULLs). It is important to note that the TRACE simulation uses approximately 30 to 65 thousand words of

```
JOB CARD
ACCOUNT CARD
COMMENT.*******************************************************************
COMMENT.            TRACE INITIALIZATION RUN
COMMENT.*******************************************************************
COMMENT.-------------------------------------------------------------------
COMMENT.     STEP 1 - GET FILES NECESSARY FOR TRACE INITIALIZATION
COMMENT.              TAPE5  - UNIT DESCRIPTIONS
COMMENT.              TAPE7  - WEAPON SYSTEM CHARACTERISTICS
COMMENT.              TAPE11 - COMMUNICATION NETWORKS
COMMENT.              TAPE12 - ELECTRONIC WARFARE
COMMENT.              TAPE2  - NEW ISPACE FILE
COMMENT.              TLIB   - TCOR SUBPROGRAM LIBRARY
COMMENT.              INIT   - INITIALIZATION PROGRAM BINARY
COMMENT.-------------------------------------------------------------------
ATTACH,TAPE91,COMBAT,ID=WDNA14CC.       GET COMBAT FACTORS
ATTACH,TAPE92,BLUEOB,ID=WDNA14CC.       GET BLUE UNIT DESCRIPTIONS
ATTACH,TAPE93,REDOB,ID=WDNA14CC.        GET RED UNIT DESCRIPTIONS
ATTACH,TAPE94,REDEWOB,ID=WDNA14CC.      GET RED EW UNIT DESCRIPTIONS
COPYBR,TAPE91,TAPE5.                    ADD TO A COMBINED FILE
COPYBR,TAPE92,TAPE5.                    ADD TO A COMBINED FILE
COPYBR,TAPE93,TAPE5.                    ADD TO A COMBINED FILE
COPYBR,TAPE94,TAPE5.                    ADD TO A COMBINED FILE
REWIND,TAPE5.                           REWIND THE COMBINED FILE
ATTACH,TAPE11,COMDATA,ID=WDNA14CC.      GET COMMUNICATIONS DATA
ATTACH,TAPE12,EWDATA,ID=WDNA14CC.       GET ELECTRONIC WARFARE DATA
REQUEST,TAPE2,*PF.                      RESERVE FILE FOR NEW ISPACE
ATTACH,INIT,TRACEINIT,ID=WDNA14CC.      GET TRACE INITIALIZATION BINARYS
ATTACH,TLIB,TRACELIB,ID=WDNA14CC.       GET TRACE PROGRAM LIBRARY
COMMENT.-------------------------------------------------------------------
COMMENT.     STEP 2 - BUILD INITIAL ISPACE
COMMENT.-------------------------------------------------------------------
LIBRARY,TLIB.
LDSET,PRESET=ZERO.
INIT,PL=20000.
COMMENT.-------------------------------------------------------------------
COMMENT.     STEP 3 - SAVE INITIAL ISPACE
COMMENT.-------------------------------------------------------------------
CATALOG,TAPE2,NEWISPACE,ID=WDNA14CC,RP=999.     SINGLE ENTRY ISPACE
COMMENT.      +++++++++                         NAME OF ISPACE
COMMENT.*******************************************************************
COMMENT.     INPUT
COMMENT.*******************************************************************
7/8/9        END OF RECORD  (JCL)
INITIALIZE                              CODE WORD FOR THE INITIALIZATION
17171274121477413155                    RANDOM NUMBER SEED
6/7/8/9      END OF FILE  (USER DIRECTIVES)
```

Figure 14. JCL deck for TRACE initialization.

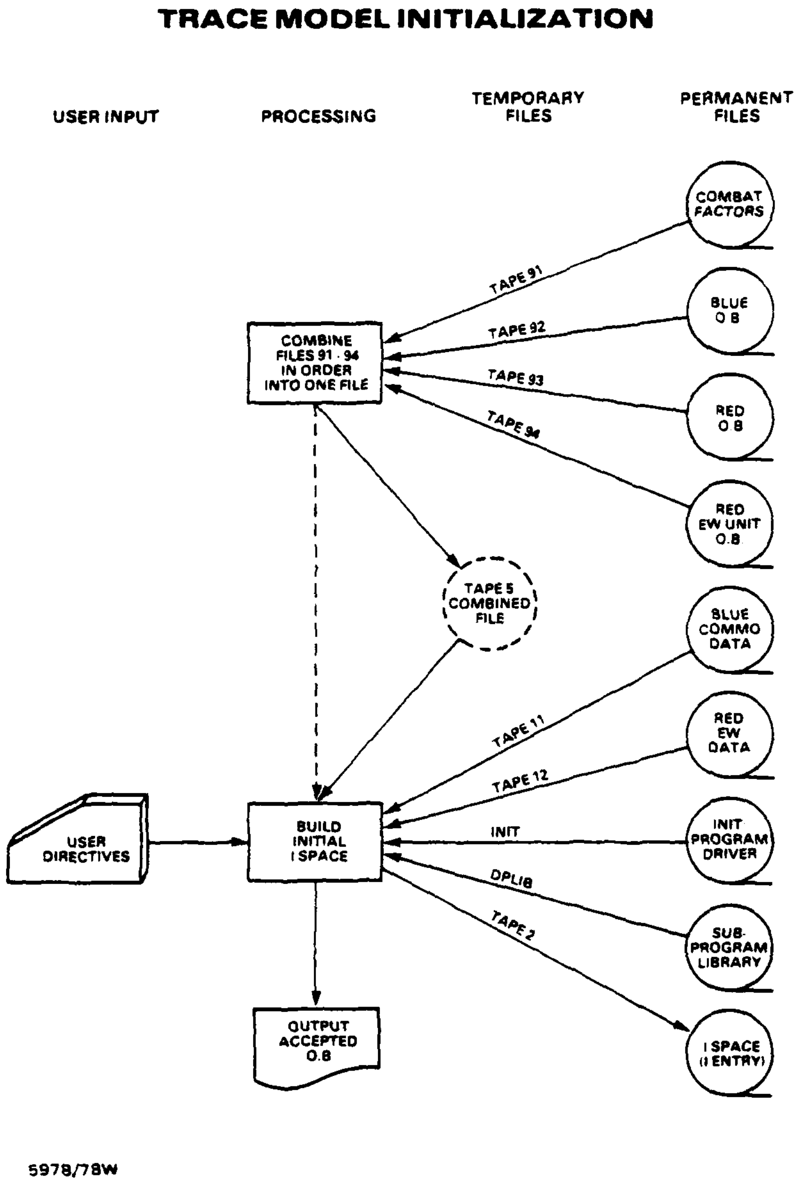

Figure 15. Model initialization process.

Cyber 176 large core memory (LCM), depending on the scenario. Hence, the job card should contain the appropriate EC or EL parameters to inform the system that LCM will be needed.

```
COMMENT.        STEP 1 - GET FILES NECESSARY FOR TRACE INITIALIZATION
```

The first step in the initialization process is to attach or reserve (as local files) all of the necessary data and program files. Four parts of one file are stored separately and must be first combined.

```
ATTACH,TAPE91,COMBAT,ID=WDNA14CC.       COMBAT FACTORS
ATTACH,TAPE92,BLUEOB,ID=WDNA14CC.       BLUE UNIT DESCRIPTIONS
ATTACH,TAPE93,REDOB,ID=WDNA14CC.        RED UNIT DESCRIPTIONS
ATTACH,TAPE94,REDEWOB,ID=WDNA14CC.      RED EW UNIT DESCRIPTIONS
COPYBR,TAPE91,TAPE5.                    ADD TO COMBINED FILE
COPYBR,TAPE92,TAPE5.                    ADD TO COMBINED FILE
COPYBR,TAPE93,TAPE5.                    ADD TO COMBINED FILE
COPYBR,TAPE94,TAPE5.                    ADD TO COMBINED FILE
REWIND,TAPE5.                           REWIND THE COMBINED FILE
ATTACH,TAPE11,COMDATA,ID=WDNA14CC.      COMMUNICATIONS DATA
ATTACH,TAPE12,EWDATA,ID=WDNA14CC.       DATA
```

These instructions attach the files containing the inputs which describe the combat scenario. The formats of these files are described in Section 2. Note that files 91, 92, 93 and 94 are combined into TAPE5 by the copy binary record directives (COPYBR).

```
REQUEST,TAPE2,*PF.
```

Reserves permanent file space for the new ISPACE that will be created and cataloged by this initialization run. The program will write the new ISPACE to this file at the end of the run.

```
ATTACH,INIT,TRACEINIT,ID=WDNA14CC.
```

Attaches the compiled version of the main initialization program. This program controls the initialization process. It is kept in a separate file from the user library since the library is designed for subprograms and not main programs.

```
ATTACH,TLIB,TRACELIB,ID=WDNA14CC.
```

Attaches, as a local file, the user library TRACELIB, which contains the compiled versions of the approximately 450 TRACE subprograms. The system loader will locate the routines needed for the simulation from the user library.

```
COMMENT.        STEP 2 - BUILD INITIAL ISPACE
```

```
LIBRARY,TLIB.
```

The computer operating system is informed that the file TLIB is a user subprogram library. This library provides all TRACE subprograms other than the main programs and some FORTRAN system routines.

```
LDSET,PRESET=ZERO.
```

The loader is instructed to preset all non-initialized memory locations to zero when the TRACE program is loaded for execution.

```
INIT,PL=20000.
```

The loader is instructed to load and execute the TRACE initialization. The main program is loaded from the file INIT, while all other routines are taken from the TLIB user library or the FORTRAN system library. The PL=20000 parameter instructs the system to set the print line limit to 20,000 lines of output.

```
COMMENT.        STEP 3 - SAVE INITIAL ISPACE
```

The purpose of the initialization is to build the initial ISPACE. After this step is completed, this initial ISPACE is saved.

```
CATALOG,TAPE2,NEWISPACE,ID=WDNA14CC,RP=999.
COMMENT.      +++++++++
```

Saves the file containing the ISPACE created by this initialization. The "++++" marks the name the file will be saved under. This catalog name is normally ISPACE10000, to correspond to the standard form ISPACEDHHMM, where DHHMM indicates the combat simulation time which this

ISPACE represents. Thus, 10000 indicates it is 12 A.M. on the first day of combat. The RP=999 parameter indicates the file is to be saved indefinitely. If this parameter is left out, the file is saved for the length of time specified by the system default (currently 10 days) and then discarded. (Depending on the size of the file it may be purged at any time regardless of the RP parameter.)

```
COMMENT.        INPUT
INITIALIZE
17171274121477413155
```

Two user directives are required. The first is the word INITIALIZE. The second is the seed for the random number generator. This permits, the user to have with no recordkeeping necessary, the all executions derived from this initialization start from the same environment. This seed is an octal (base 8) integer, 20 digits long. (The random number seed may be overridden at execution if desired by the user.)

3.3 MITL PROCESSING

Before the simulation can be run or the course of the battle changed, the user (man-in-the-loop) must issue orders to the units in the simulation. (See Chapter 2 for an explanation of the format of these orders.) Figure 16 lists the JCL required to process these orders. Figure 17 depicts this processing. The remainder of this section details the JCL.

JCL EXPLANATION (MITL PROCESSING)

```
JOB CARD.
ACCOUNT CARD.
```

The job and account card formats for the AFWL computer system are described in AFWL's system bulletins (SYSBULLs). It is important to note that the TRACE simulation uses approximately 30 to 65 thousand words of Cyber 176 large core memory (LCM), depending on the scenario. Hence, the job card should contain the appropriate EC or EL parameters to inform the system that LCM will be needed.

```
JOB CARD
ACCOUNT CARD
COMMENT.*****************************************************************
COMMENT.                 TRACE MAN-IN-THE-LOOP (MITL)
COMMENT.*****************************************************************
COMMENT.-----------------------------------------------------------------
COMMENT.       STEP 1 - GET THE NECESSARY FILES
COMMENT.-----------------------------------------------------------------
ATTACH,TLIB,TRACELIB,ID=WDNA14CC.   GET TRACE SUBPROGRAM LIBRARY
ATTACH,TAPE3,ISPACES,ID=WDNA14CC.   GET OLD ISPACES
COMMENT.     +++++++                NAME OF ISPACES FROM PREVIOUS RUN
REQUEST,TAPE47,*PF                  RESERVE FILE FOR ORDERS
ATTACH,MITL,TRACEMITL,ID=WDNA14CC.  GET MITL BINARY
COMMENT.-----------------------------------------------------------------
COMMENT.       STEP 2 - PROCESS MITL DIRECTIVES
COMMENT.-----------------------------------------------------------------
LIBRARY,TLIB.
LDSET,PRESET=ZERO.
MITL.
COMMENT.-----------------------------------------------------------------
COMMENT.       STEP 3 - SAVE GENERATED ORDERS
COMMENT.-----------------------------------------------------------------
CATALOG,TAPE47,ORDERSDHHMM,ID=WDNA14CC,RP=999
COMMENT.     +++++++++++            NEW ORDERS FILE
COMMENT.*****************************************************************
COMMENT.       INPUT DATA
COMMENT.*****************************************************************
7/8/9          END OF RECORD    (JCL)
INITIAL DIRECTIVES
6/7/8/9        END OF FILE      (USER DIRECTIVES)
```

Figure 16. JCL for TRACE MITL processing.

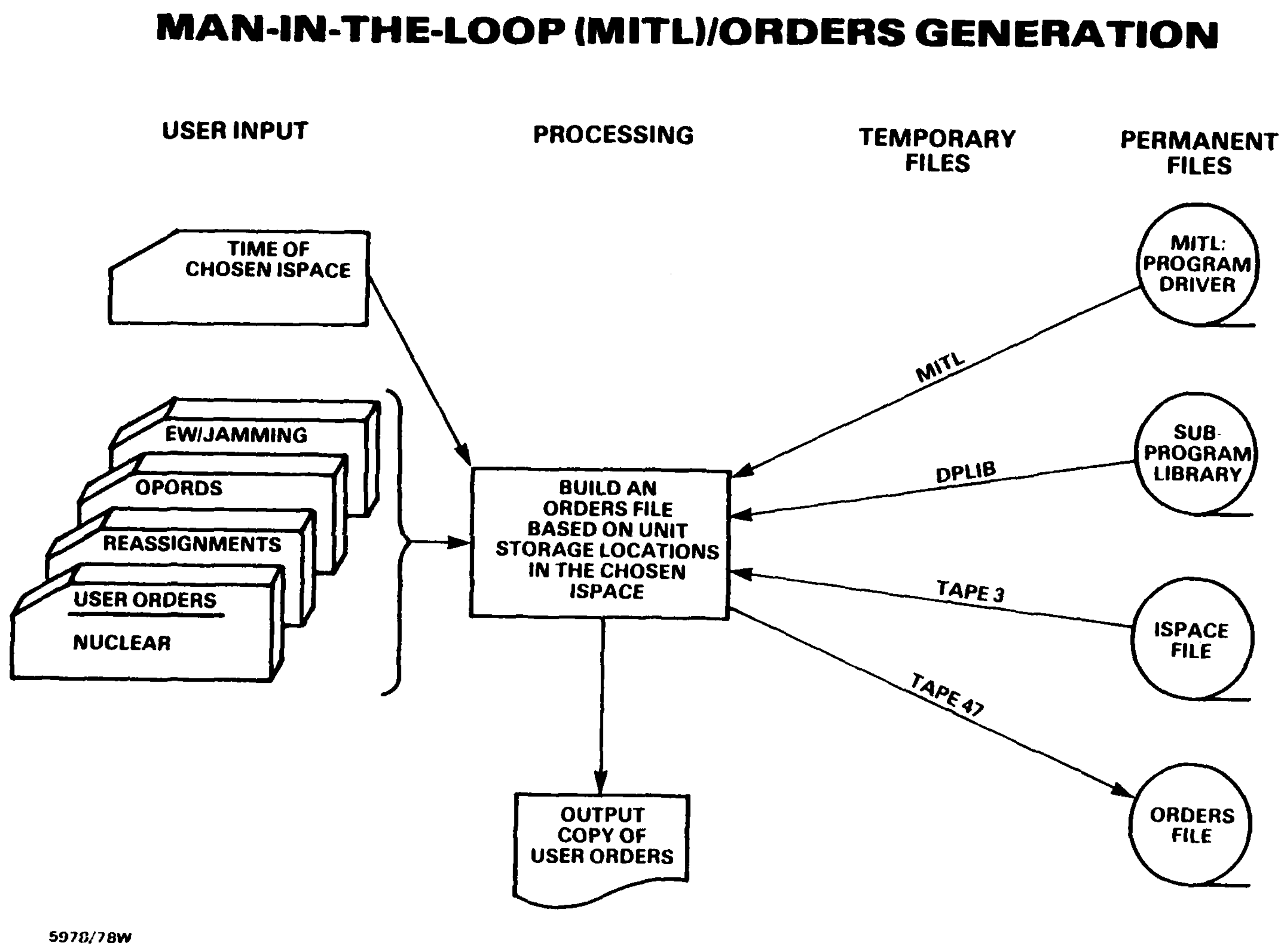

Figure 17. Man-in-the-loop orders generation process.

```
COMMENT.        STEP 1 - GET THE NECESSARY FILES
```

The first step in the MITL processing is to attach or reserve (as a local file) all of the necessary program and data files.

```
ATTACH,TLIB,TRACELIB,ID=WDNA14CC.
```

Attaches, as a local file, the user library TRACELIB, which contains the compiled versions of the approximately 450 TRACE subprograms. The system loaders will locate the routines needed for the simulation from the library.

```
ATTACH,TAPE3,ISPACES,ID=WDNA14CC.
COMMENT.    ++++++
```

Attaches the file containing the ISPACEs from some previous execution or initialization run. The name of the file, underscored by "++++", is the same that was used to catalogue the ISPACE file in the previous run. It is usually of the form ISPACEDHHMM.

```
REQUEST,TAPE47,*PF
```

Reserves permanent file space for the orders that will result from the processing of the MITL directives.

```
ATTACH,MITL,TRACEMITL,ID=WDNA14CC.
```

Attaches the compiled version of the main MITL processing program. This program drives the processing of the MITL directives. It is kept in a separate file from the user library since the library is designed for subprograms and not main programs.

```
COMMENT.        STEP 2 - PROCESS MITL DIRECTIVES
LIBRARY,TLIB.
```

The computer operating system is informed that the file TLIB is a user subprogram library. This library provides all TRACE subprograms other than the main programs and some FORTRAN system routines.

LDSET,PRESET=ZERO.

The loader is instructed to preset all non-initialized memory locations to zero when the TRACE program is loaded for execution.

MITL.

The loader is instructed to load and execute the MITL processing. The main program is loaded from the file MITL and all other routines are taken from the TLIB user library or the FORTRAN system library.

COMMENT.   STEP 3 - SAVE GENERATED ORDERS

CATALOG,TAPE47,ORDERSDHHMM,ID=WDNA14CC,RP=999.
COMMENT.   +++++++++++

Saves the file containing the orders generated from the MITL directives. The "++++" underscores the name used to catalogue the file. DHHMM indicates the time in the ISPACES file to which the orders are hook. This time is important because there is a high degree of dependancy in the order on the memory layout pictured in the ISPACES file, at the time point chosen.

COMMENT.   INPUT DATA

(The MITL directives are explained in Section 2.)

3.4 SIMULATION EXECUTION

The TRACE execution phase consists of a series of combat simulations for specified periods of time. At the beginning of each of these simulations, new operations orders for both Red and Blue are input. See section 2.4.1 for a description of this input. At the end of each simulation period, the results are analyzed, and decisions are made concerning the orders for the next period.

Each simulation in this execution phase begins with an ISPACE and ends with an updated ISPACE. Multiple, intermediate ISPACEs may also be saved. The ISPACE is the dynamic storage array containing all the data and list structures which determine the current status of the simulation. The combat simulation can be stopped at any point in time and restarted again by saving this ISPACE array and then reloading it later.

Figure 18 lists the JCL necessary for each simulation in the execution phase while Figure 19 depicts this process. The remainder of this section provides a detailed explanation of each JCL step.

JCL EXPLANATION (EXECUTION PHASE)

```
JOB CARD.
ACCOUNT CARD.
```

The job and account card formats for the AFWL computer system are described in AFWL's system bulletins (SYSBULLs). It is important to note that the TRACE simulation uses approximately 30 to 65 thousand words of Cyber 176 large core memory (LCM), depending on the scenario. Hence, the job card should contain the appropriate EC or EL parameters to inform the system that LCM will be needed.

```
COMMENT.        STEP 1 - GET FILES NECESSARY FOR TRACE SIMULATION
```

The first step in the simulation process is to attach or reserve (as local files) all of the necessary data and program files.

```
COPYBR,INPUT,TAPE24.
REWIND,TAPE24.
```

Get the first file record off the input (up to 100 cards or logical records) and copy it to file TAPE24. This file contains the description of this execution. The file is then rewound for use.

```
ATTACH,TLIB,TRACELIB,ID=WDNA14CC.
```

Attaches, as a local file, the user library TRACELIB, which contains the compiled versions of the approximately 450 TRACE subprograms. The system loader will locate the routines needed for the simulation from this user library.

```
JOB CARD
ACCOUNT CARD
COMMENT.*******************************************************************
COMMENT.                 TRACE SIMULATION EXECUTION
COMMENT.*******************************************************************
COMMENT.-------------------------------------------------------------------
COMMENT.  STEP 1 - GET FILES NECESSARY FOR TRACE SIMULATION:
COMMENT.       TAPE3  - LAST ISPACE FROM PREVIOUS RUN
COMMENT.       TAPE2  - STATISTICS FILE FOR POST PROCESSOR
COMMENT.       TAPE9  - MITL ORDERS FILE
COMMENT.       TAPE24 - RUN DESCRIPTION
COMMENT.       TAPE31 - FILE ON WHICH NEW ISPACE WILL BE WRITTEN
COMMENT.       TLIB   - TRACE SUBPROGRAM LIBRARY
COMMENT.       TRACE  - MAIN PROGRAM BINARY
COMMENT.-------------------------------------------------------------------
COPYBR,INPUT,TAPE24                     GET RUN DESCRIPTION ONTO FILE
REWIND,TAPE24.                          REWIND FILE
ATTACH,TLIB,TRACELIB,ID=WDNA14CC.       GET TRACE SUBPROGRAM LIBRARY
ATTACH,TAPE9,ORDERSDHHMM,IDSWDNA14CC.   GET ORDERS FILE
COMMENT.     +++++++++++                NAME OF ORDERS FROM MITL
ATTACH,TAPE3,ISPACES,ID=WDNA14CC.       GET OLD ISPACES
COMMENT.     +++++++                    NAME OF ISPACES FROM PREVIOUS RUN
ATTACH,TCOR,TRACEEXEC,ID=WDNA14CC.      GET TRACE BINARY
REQUEST,TAPE31,*PF.                     RESERVE FILE FOR NEW ISPACES
REQUEST,TAPE2,*PF.                      RESERVE FILE FOR RUN STATISTICS
COMMENT.-------------------------------------------------------------------
COMMENT.  STEP 2 - EXECUTE TRACE SIMULATION
COMMENT.-------------------------------------------------------------------
LIBRARY,TLIB.
LDSET,PRESET=ZERO.
TRACE,PL=20000.
COMMENT.-------------------------------------------------------------------
COMMENT.  STEP 3 - SAVE RESULTS FROM THIS SIMULATION
COMMENT.-------------------------------------------------------------------
CATALOG,TAPE31,NEWISPACE,ID=WDNA14CC,RP=999.
COMMENT.       +++++++++                NAME OF NEW ISPACES
CATALOG,TAPE2,THISSTATFILE,ID=WDNA14CC,RP=999.
COMMENT.      ++++++++++++              NAME OF RUN STATISTICS FILE.
REWIND,TAPE55.
COPY,TAPE55,OUTPUT.      COPY SIGINT INFORMATION TO OUTPUT
REWIND,TAPE73.
COPY,TAPE73,OUTPUT.      COPY BLUE MESSAGES RECEIVED TO OUTPUT.
COMMENT.*******************************************************************
COMMENT.                      INPUT DATA
COMMENT.*******************************************************************
7/8/9          END OF RECORD   (JCL)
run description
7/8/9          END OF RECORD   (RUN DESCRIPTION)
EXECUTE                            CODE WORD FOR THE EXECUTION
user directives
6/7/8/9   END OF FILE     (USER DIRECTIVES)
```

Figure 18. JCL for TRACE execution run.

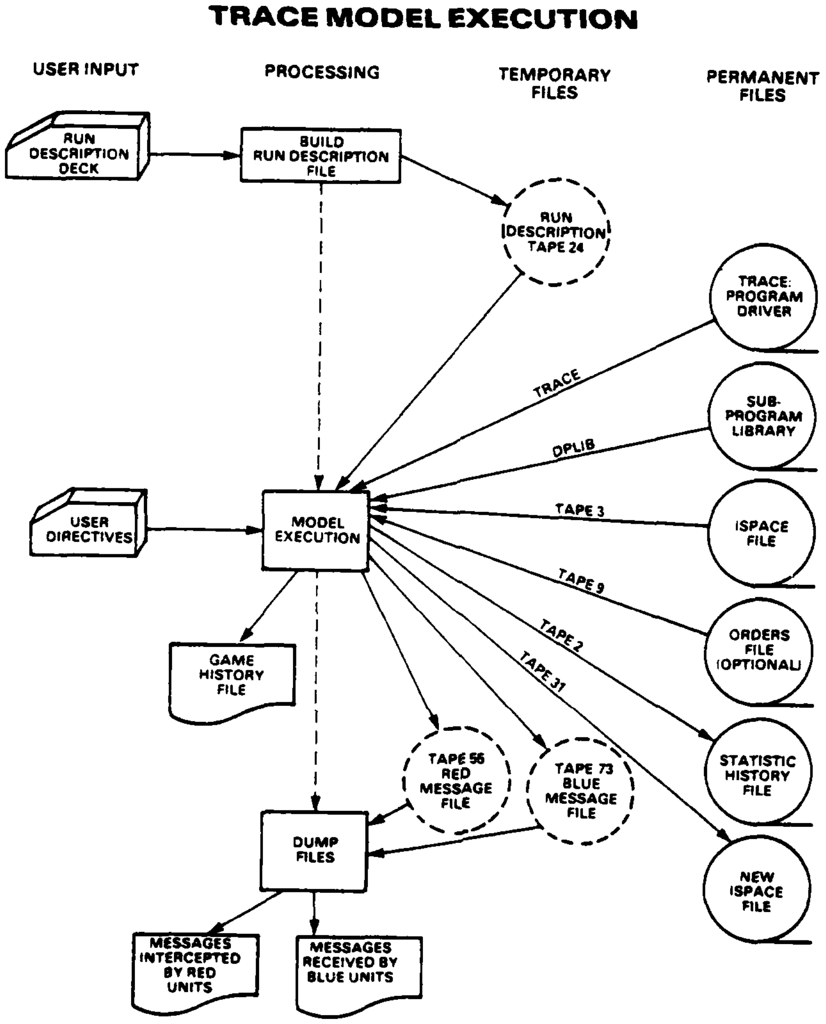

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Figure 19. TRACE model execution process.

```
ATTACH,TAPE9,ORDERSDHHMM,ID=WDNA14CC.
COMMENT.     +++++++++++
```

Attaches the file containing the orders from a MITL processing. The name "ORDERSDHHMM", underscored by "++++", is the file name used to catalog the orders in the MITL run. The DHHMM refers to the time of the ISPACE to which the orders were hooked in the MITL processing. (See immediately below for format of DHHMM.)

```
ATTACH,TAPE3,ISPACES,ID=WDNA14CC.
COMMENT.     +++++++
```

Attaches the file containing the ISPACEs from some previous execution or initialization run. The name "ISPACES", underscored with "++++" for user convenience, is the file name under which the ISPACEs were cataloged. This catalog name is normally a name of the form ISPACEDHHMM, where DHHMM indicates the combat simulation time at which the run put the first ISPACE on the file:

 D - day of combat (1-9)
HH - hour (00-23)
MM - minute (00-59)

For example, if the name of the last ISPACE was ISPACE10800, this would indicate that a prior simulation put the first ISPACE on the file on the first day of combat, and hence, this next simulation run would begin at that time or some later time if any more timepoints exist on the file.

```
ATTACH,TRACE,TRACEEXEC,ID=WDNA14CC.
```

Attaches the compiled version of the main simulation program. This program controls the execution of the simulation. It is kept in a separate file from the user library, since the library is designed for subprograms and not main programs.

```
REQUEST,TAPE2,*PF
```

Reserves permanent file space for the history statistics that will be generated by this run and saved for use by a post processor.

```
REQUEST,TAPE31,*PF.
```

Reserves permanent file space for the new ISPACE that will be created and cataloged by this simulation run. The main program will write the new ISPACE to this file at the end of the run.

```
COMMENT.        STEP 2 - EXECUTE TRACE SIMULATION
```

After all the necessary files have been attached or reserved, the following instructions begin the running of the TRACE simulation.

```
LIBRARY,TLIB.
```

The operating system is informed that the file TLIB is a user subprogram library. This library provides all the TRACE subprograms other than the main programs and the FORTRAN system routines.

```
LDSET,PRESET=ZERO.
```

The loader is instructed to preset all non initialized memory locations to zero when the TRACE program is loaded for execution.

```
TRACE,PL=20000.
```

The loader is instructed to load and execute the TRACE simulation. The main program is loaded from the file TRACE, while all other routines are loaded from the TLIB user library or the FORTRAN system library. The PL=20000 parameter sets the system print line limit to 20,000 lines of output. If the simulation generates more than this number of lines, an error will occur and the program will abort.

```
COMMENT.        STEP 3 - SAVE RESULTS FROM THIS SIMULATION
```

When this run is complete, history statistics and updated ISPACEs may be saved, and the Blue message file and Red SIGINT file are copied to the line printer.

```
CATALOG,TAPE2,THISSTATFILE,ID=WDNA14CC,RP=999.
COMMENT.      ++++++++++++     NAME OF RUN STATISTICS FILE
```

Saves the file containing the history statistics if one is generated by this run. (See user directives, Section 2.) The "++++" underscores the name under which this file is saved. This name is usually of the form TRACEDHHMMJJJ. The DHHMM is the same as for the ISPACE file. JJJ is the Julian date the simulation was run. RP=999 indicates an indefinite retention period.

```
CATALOG,TAPE31,NEWISPACE,ID=WDNA14CC,RP=999.
COMMENT.       +++++++++
```

Saves the file containing the ISPACEs updated by this simulation run. This file will be generated only if the user directs. See description of user directives in Section 2. The "++++" underscores for user convenience the name under which this file will be saved. This catalog name is usually of the form ISPACEDHHMM, as described above (see explanation of ATTACH,TAPE3, LASTISPACE, . . . instruction). The RP=999 parameter indicates the file is to be saved indefinitely. If this parameter is left out, the file will be saved for the system default length of time (currently 10 days) and then discarded.

```
REWIND,TAPE73.
COPY,TAPE73,OUTPUT.
```

TRACE builds a local file, TAPE73, containing a copy of all the messages received by BLUE commanders. At the end of the simulation, this file is rewound and copied to the line printer. See section 4.3 for an explanation of this information.

```
REWIND,TAPE55.
COPY,TAPE55,OUTPUT.
```

The TRACE simulation writes signal intelligence and direction finding information to the local file TAPE55. At the end of the simulation, the file is reset to the beginning of written information, and then copied to the line printer. See section 4.4 for a description of this SIGINT output.

COMMENT. INPUT DATA

As the TRACE simulation begins execution, two input sets are read. These input sets are separated by the end of record markers (a card with 7/8/9 punched in the first column), and are read in the order shown in Figure 18.

The first input set is a user supplied run description or title page for the simulation output. TRACE reads and prints card images until it reaches an end of record. The user can include comments here that will provide information on this particular simulation run. This can be up to 100 cards and will be stored with the POST PROCESSOR file if one is generated.

The second input set begins with a card with the word EXECUTE in columns 1-7. This is the code for an execution of TRACE. Following this card are the user directives as explained in Section 2.5.

3.5 TRACE POST PROCESSOR

A history statistics file may be generated by user directived during each run of the TRACE simulation. This file is stored and a selection of output may be generated from it at a later date. The generation of these outputs is detailed in Chapter 4.

Figure 20 lists the JCL needed to run this post processor and the remainder of this section explains the JCL in detail. Figure 21 depicts this processing.

JCL EXPLANATION (POST PROCESSOR)

JOB CARD.

ACCOUNT CARD.

The job and account card formats for the AFWL computer system are described in AFWL's system bulletins (SYSBULLs). It is important to note that the TRACE simulation uses approximately 30 to 65 thousand words of

```
JOB CARD
ACCOUNT CARD
COMMENT.*******************************************************************
COMMENT.                 TRACE POST PROCESSOR
COMMENT.*******************************************************************
COMMENT.-------------------------------------------------------------------
COMMENT.       STEP 1 - GET NECESSARY FILES
COMMENT.-------------------------------------------------------------------
ATTACH,TLIB,TRACELIB,ID=WDNA14CC.       GET TRACE SUBPROGRAM LIBRARY
ATTACH,POST,TRACEPOSTPROC,ID=WDNA14CC.  GET TRACE POST PROCESSOR BINARY
ATTACH,TAPE1,OLDSTATFILE,ID=WDNA14CC.   GET A HISTORY STATISTICS FILE
COMMENT.     +++++++++++                NAME OF STATISTICS FILE
COMMENT.-------------------------------------------------------------------
COMMENT.       STEP 2 - PROCESS USER REQUESTS
COMMENT.-------------------------------------------------------------------
LIBRARY,TLIB.
POST,PL=40000.
COMMENT.-------------------------------------------------------------------
COMMENT.                 INPUT DIRECTIVES
COMMENT.-------------------------------------------------------------------
7/8/9          END OF RECORD  (JCL)
user directives
6/7/8/9   END OF FILE    (USER DIRECTIVES)
```

Figure 20. JCL for TRACE post processor.

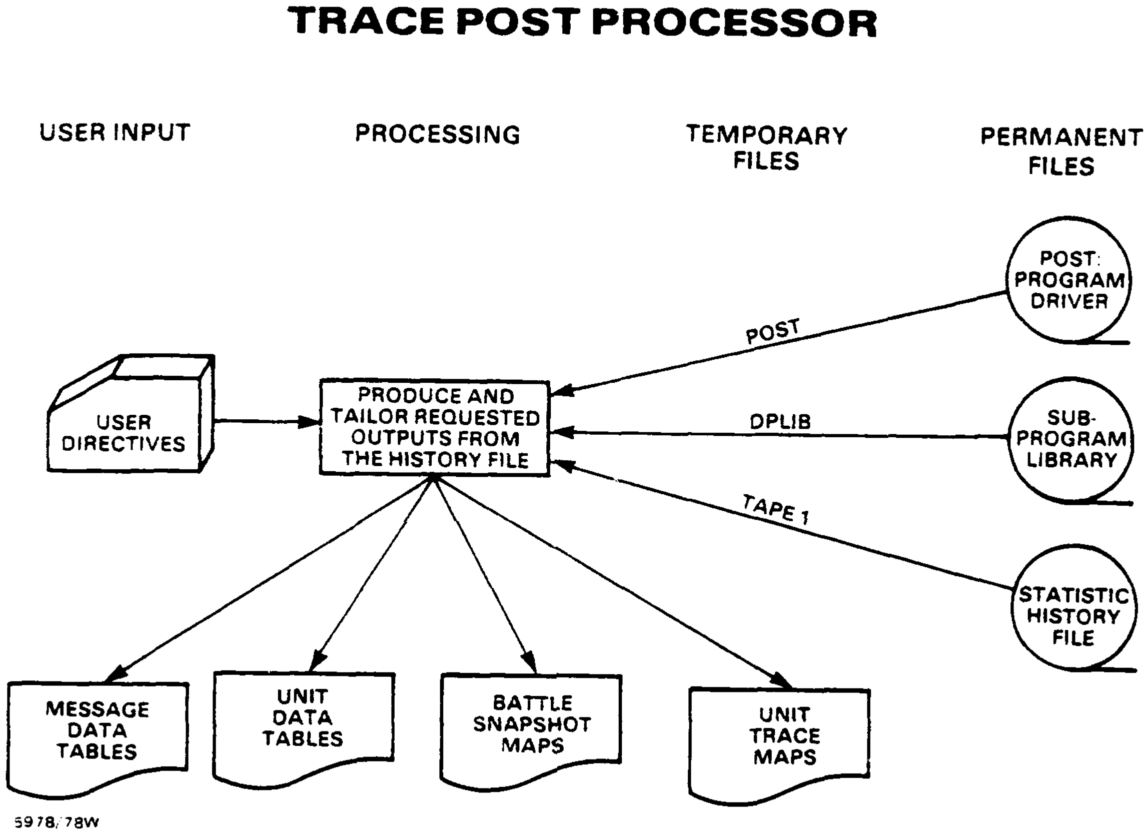


Figure 21. TRACE post processing process.

Cyber 176 large core memory (LCM), depending on the scenario. Hence, the job card should contain the appropriate EC or EL parameters to inform the system that LCM will be needed.

```
COMMENT.        STEP 1 - GET NECESSARY FILES
```

The first step is to attach the necessary program and data files.

```
ATTACH,TLIB,TRACELIB,ID=WDNA14CC.
```

Attaches, as a local file, the user library TRACELIB, which contains the compiled versions of the approximately 450 TRACE subprograms. The system loader will locate the routines needed for the simulation from the user library.

```
ATTACH,POST,TRACEPOSTPROC,ID=WDNA14CC.
```

Attaches the compiled version of the main processing program. This program chooses which subprograms to activate to handle each of the user directives. It is kept on a separate file from the user library since the library is designed for subprograms not main programs.

```
ATTACH,TAPE1,OLDSTATFILE,ID=WDNA14CC.
COMMENT.     +++++++++++
```

Attaches the file containing the history statistics. This file was generated by some previous execution of the TRACE simulation. The file name, underscored by "++++", is usually in the form TRACEDHHMMJJJ. DHHMM is the first time point that appears on the file. JJJ is the Julian date that the file was created.

```
COMMENT.        STEP 2 - PROCESS USER REQUESTS
LIBRARY,TLIB.
```

The computer operating system is informed that the file TLIB is a user subprogram library. This library provides all TRACE subprograms other than the main programs and some FORTRAN system routines.

POST,PL=40000.

The loader is instructed to load and execute the post processor. The main program is loaded from the file POST and all other routines are loaded from the TLIB user library or the FORTRAN system library. The PL=40000 parameter instructs the system to set the print line limit to 40,000 line of output. This is large due to the tabular nature of the output. It may be reduced once a standard pattern of user directives is established for a particular user.

COMMENT. INPUT DIRECTIVES

The user directives may come in any order and are described in Section 4.

SECTION 4
SIMULATION OUTPUTS

4.1 INTRODUCTION

During the execution of a TRACE simulation run, four different types of output are generated:

(1) A running commentary of significant events occurring during the simulation including the status of the unit affected;

(2) Overall status summaries of Red and Blue forces down to battalion or company level;

(3) Blue messages received;

(4) Signal intelligence and direction finding information obtained by Red forces.

After completion of a TRACE simulation run, a post processor may be applied to a generated file. Four types of outputs are available from this post processor:

(1) Tables of message statistics;

(2) Tables of unit statistics;

(3) Hex maps of a snapshop of the battlefield;

(4) Hex maps tracing the movement of designated units.

The following paragraphs describe each of these output types in greater detail.

4.2 RUNNING COMMENTARY

The running commentary output provides a detailed chronological listing of major events occurring during a TRACE simulation run. Each line of the commentary identifies a specific event or situation and the unit involved. If the unit is at the company level, its commander is also identified. In addition, the unit's position, speed, direction of movement, and materiel on hand and lost are indicated. Some of the comments are not printed out 100% of the time that the corresponding event occurs. Instead a random selection of these events is chosen to be printed, based on the relative importance of the event.

Figure 22 shows the heading which appears on each page of the running commentary output and a few sample lines of this output. The following information is printed with each comment:

1. TIME The simulation time at which this comment was generated is expressed in the format DHHMM:SS. Here D indicates the day of the conflict starting with day 1, HH indicates the hour using a 24 hour clock, MM indicates the minute, and SS indicates the second.

2. SIDE This is either RED for Warsaw Pact forces or BL (BLUE) for NATO forces.

3. COMMANDER The command unit affected by this event or situation is identified by unit number and type. The possible unit types are listed with the description of the input language UOIL in Appendix C. The command unit is always at the battalion level or above. If a company level unit is specified under COMPANY, it is a subordinate of this unit.

4. COMPANY The company level unit, if any, affected by this event or situation is identified by unit number and type. If the comment pertains only to a command unit and to no particular company level subordinate, this section is left blank and the position, materiel and movement information refers to the command unit specified under COMMANDER. Otherwise, the position, materiel, and movement information pertains to the company level unit specified here.

5. POSITION This is the hex address of the unit affected. For a description of hex addresses see Appendix A.

Figure 22 shows the heading which appears on each page of the running commentary output and a few sample lines of this output. The following information is printed with each comment:

1. TIME — The simulation time at which this comment was generated is expressed in the format DHHMM:SS. Here D indicates the day of the conflict starting with day 1, HH indicates the hour using a 24 hour clock, MM indicates the minute, and SS indicates the second.

2. SIDE — This is either RED for Warsaw Pact forces or BL (BLUE) for NATO forces.

3. COMMANDER — The command unit affected by this event or situation is identified by unit number and type. The possible unit types are listed with the description of the input language UOIL in Appendix C. The command unit is always at the battalion level or above. If a company level unit is specified under COMPANY, it is a subordinate of this unit.

4. COMPANY — The company level unit, if any, affected by this event or situation is identified by unit number and type. If the comment pertains only to a command unit and to no particular company level subordinate, this section is left blank and the position, materiel and movement information refers to the command unit specified under COMMANDER. Otherwise, the position, materiel, and movement information pertains to the company level unit specified here.

5. POSITION — This is the hex address of the unit affected. For a description of hex addresses see Appendix A.

```
  TIME     SIDE  COMMANDER      COMPANY       POSITION  TANK      INF      TUBE        AMMO       SPD  DIR         REMARKS
(DHHMM:SS)       UNIT   TYPE   UNIT  TYPE               O/H   L  O/H  L  O/H  L    O/H       E (KM/HR)
 10621:08 BL       3   ARMBDE                  7777724  144   1  123  1           11035    384     .90 SE   STATUS RPT RECEIVED
 10629:40 RED     13    TKBN    131   TKCO   777761535   10
                                                                                    400          10.91 WSW    NONCOMBAT MOVE
 10633:36 BL      31   MECHBN   312  MECCO   777772674             11  2
                                                                                     43     85   18.22 WNW     REQUEST ARTY
 10640:49 RED     11    TKBN    112   TKCO   777772643    6   4
                                                                                    282    118     .22 WSW    CAS CASUALTIES
 10648:32 BL      31   MECHBN   312  MECCO   777772617             10  3             43     85    0.00 ---     COMBAT LOSS
```

Figure 22. Example TRACE running commentary.

6. TANK The number of tanks the affected unit has on hand (O/H) and has lost (L) are indicated. For simulation purposes a single tank is a normalized quantity representing approximatley one tank with crew.

7. INF The number of antitank units (ATU's) the affected unit has on hand (O/H) and has lost (L) are indicated. An ATU represents approximately one infantry squad.

8. TUBE The number of artillery tubes the affected unit has on hand (O/H) and has lost (L) are indicated. A single tube is a normalized quantity representing approximately one 155mm gun with crew.

9. AMMO This lists the rounds of ammunition the affected unit has on hand (O/H) and has expended (E).

10. SPD The current speed of the affected unit is given in kilometers per hour.

11. DIR The approximate direction of movement of the affected unit is indicated. If the unit is at rest, a series of dashes is printed. Otherwise the direction is rounded to the nearest of the 16 basic compass directions:

N, NNE, NE, ENE,
E, ESE, SE, SSE,
S, SSW, SW, WSW,
W, WNW, NW, NNW.

12. REMARKS A brief comment printed here identifies the event or situation which has occurred. For a complete list and explanation of all possible remarks see Appendix B.

The first sample comment in Figure 22 shows that the 3rd Armored Brigade on the Blue side received a status report from a subordinate at approximately 0621 hours on the first day of the conflict. This brigade was located at hex 7777724 and was moving at a rate of 0.9 kilometers per hour in a southeasterly direction. So far it had expended 384 rounds of ammunition and had lost 1 tank and 1 ATU.

The next example in the figure indicates that the 131st Tank Company of the 13th Red Tank Battalion has just advanced west southwest into hex 777761535. It was not in combat and had suffered no losses as of 0629 hours.

At 0633 hours the 312th Mech Company of the 31st Blue Mech Battalion had lost 2 ATUs and had 11 remaining. It was engaged in combat and just requested conventional artillery fire against an enemy unit.

The final two comments in the sample output in Figure 22 indicate that the listed units have just suffered casualties due to enemy close air support and direct ground fire, respectively.

4.3 STATUS SUMMARIES

At periodic intervals the TRACE simulation may be interrupted, according to user directive, to print out complete status summaries of Red and Blue forces. This can be done either down to battalion level units only or all the way down to company level units.

The status summary output begins with a heading which takes the form:

```
TIMEOUT FOR "side" "level" STATUS
```

where "side" is either RED or BLUE, and "level" is either BATTALION or COMPANY. Following this heading appears the same heading as on each page of the running commentary. Then the status of each unit at or above the specified level of command is indicated in the running commentary format. Figure 23 shows two examples of status summary output at 0750 hours on the first day of the conflict. Red status is shown here down to battalion level units and Blue status down to company level units. In each case only the first several lines of the output are included in the figure. Note that the comment appearing in the REMARKS column is always PRESENT STATUS.

```
TIMEOUT FOR RED BATTALION STATUS

  TIME     SIDE  COMMANDER      COMPANY    POSITION  TANK     INF      TUBE        AMMO        SPD  DIR        REMARKS
(DHHMM:SS)       UNIT   TYPE   UNIT TYPE            O/H   L  O/H  L  O/H  L    O/H      E  (KM/HR)

10750:00 RED    1  TK ARMY                   77776 300   16  88  15  222       31656  1762    .90 WNW PRESENT STATUS
10750:00 RED    9   TKDIV                   777761 300   16  87  15  222       31625  1762    .94 NW  PRESENT STATUS
10750:00 RED    8   RECRGT                 7777614           13                  403          0.00 --- PRESENT STATUS
10750:00 RED   82   RECBN                 77776533            6                  186          0.00 --- PRESENT STATUS
10750:00 RED   81   RECBN                 77776155            6                  186          0.00 --- PRESENT STATUS
10750:00 RED    9  ARTYRGT                 7777614           17       72        5915          0.00 --- PRESENT STATUS
10750:00 RED   94   ARTYBN                77776152            4       18        1471          0.00 --- PRESENT STATUS
10750:00 RED   93   ARTYBN                77777623            4       18        1471          0.00 --- PRESENT STATUS
10750:00 RED   92   ARTYBN                77776156            4       18        1471          0.00 --- PRESENT STATUS
```

```
TIMEOUT FOR BLUE COMPANY STATUS

  TIME     SIDE  COMMANDER      COMPANY     POSITION  TANK     INF      TUBE        AMMO        SPD  DIR        REMARKS
(DHHMM:SS)       UNIT   TYPE   UNIT TYPE             O/H   L  O/H  L  O/H  L    O/H      E  (KM/HR)

10750:00 BL     5    CORPS                    77777 180   19 180  19  90       29617  3432    .29 WNW PRESENT STATUS
10750:00 BL     5    CORPS     5    HHC   777773277              1                40          0.00 --- PRESENT STATUS
10750:00 BL     3    ARMDIV                  777772 180   19 179  19  90       29577  3432    .32  N  PRESENT STATUS
10750:00 BL     3    ARMDIV    3    HHC   777772733              1                40          0.00 --- PRESENT STATUS
10750:00 BL     4   DIVARTY                 7777727             25      90     17515     9    .79 SSW PRESENT STATUS
10750:00 BL     4   DIVARTY   40    HHB   777772734              1                40          0.00 --- PRESENT STATUS
10750:00 BL    46    ARTYBN                77777276              4      18      4252          4.54 SSE PRESENT STATUS
10750:00 BL    46    ARTYBN  463  BTY155  777772435              1       6      1289   115    0.00 --- PRESENT STATUS
10750:00 BL    46    ARTYBN  462  BTY155  777772244              1       6      1358    46    0.00 --- PRESENT STATUS
```

Figure 23. Example status summaries.

4.4 BLUE MESSAGE FILE

TRACE collects a copy of every message received by any BLUE commander and displays them in the order received. A listing of all these messages is made at the end of each simulation run. For each message there is a summary of the characteristics of the communications net over which the message was transmitted. The message context and senders location are also displayed. Figure 24 is a sample of the BLUE message file output.

4.4.1 Communication Network Characteristics

For each message sent, there is a line of output providing all known characteristics of the communication net. The following is a list and explanation of these characteristics:

(1) Time at which message is sent.

- Time is presented in the standard form used in this simulation: in days, hours, and minutes (DHHMM) - one digit for the day of combat, two digits for the hour, and two digits for the minute. For example, the time 10629 represented 6:29 A.M. on the first day of combat.

(2) Transmission frequency of communication net - in megahertz (MHZ).

(3) Transmission mode of the communication net.

- VOICE, teletype (TTY), or facsimile (FAX).

(4) Security level of the message.

(5) Net command level and traffic type.

- This information is provided only if message was transmitted in the clear.
- Command level refers to echelon of the net control station:

Corps	(COR)
Division	(DIV)
Brigade	(BDE)
Battalion	(BN)

```
/ TIME/   FREQ    / MODE/SECUR/      NET     //      SENDER     //   RECEIVER    //
 DHHMM   (MHZ)            LEVEL

/10045/ 61.500 MHZ/VOICE/CLEAR/NET: BDE CMD  //FROM:  2  ARMBDE //TO: 23  ARMBN  //
                 OP ORDER     : DEFEND OBJECTIVE 777776317 EFFECTIVE TIME: 10230
         SENT FROM UNIT AT HEX        7777724 AT TIME  10037

/10045/ 55.750 MHZ/VOICE/CLEAR/NET: BDE ARTY //FROM: 21  MECHBN //TO: 44  ARTYBN //
                 ARTY REQUEST : SHOOT AT - 777776371
         SENT FROM UNIT AT HEX       77777631 AT TIME  10044

/10045/ 15.272 MHZ/VOICE/CLEAR/NET: COR CAS  //FROM: 11  MECHBN //TO:  5  CORPS  //
                 CAS REQUEST  : ATTACK ENEMY UNIT AT - 777772624
         SENT FROM UNIT AT HEX       77777267 AT TIME  10043

/10053/ 44.050 MHZ/VOICE/CLEAR/NET: BDE INTEL//FROM: 21  MECHBN //TO:  2  ARMBDE //
                 INTEL REPORT :RED   TKCO   LOCATED 777776375 HEADING WSW
         SENT FROM UNIT AT HEX       77777631 AT TIME  10051
```

Figure 24. Example Blue message file output.

- Net traffic type corresponds to tne normal type of message sent over this net:

Command Net	(CMD)
Adminstrative Net	(ADMIN)
Artillery Requst Net	(ARTY)
Intelligence Report Net	(INTEL)
Close Air Support Request Net	(CAS)
Messenger (No net was available)	(MSNGR)

(6) Sender and receiver of message.
The unit number and unit type of sender and receiver was listed. For example, if the 31st Mechanized Battalion had sent a message to the 3rd Armored Brigade, the sender and receiver portion of the output would be:

```
//FROM:          31 MECHBN       //TO:            3 ARMBDE//
```

The following is an example of a message transmitted by voice at 15.272 megahertz over the Corps Close Air Support Request Net from the 31st Mechanized Battalion to the 5th Corps.

```
/10629/ 15.272 MHZ/VOICE/CLEAR/NET: COR CAS //FROM:  31 MECHBN //TO: 5 CORPS//
```

4.4.2 Message Content

In addition to net characteristics, the content of a message is output. There are six basic types of messages being transmitted in TRACE (one type, the logistics, is not yet implemented):

(1) Operations orders from a commander to his subordinate
- An operations order consists of a directive for a subordinate to either attack or defend a certain location by a given effective time.
- Sample output:

```
OP ORDER  :  DEFEND OBJECTIVE 777772727 EFFECTIVE TIME 10830
```

This is an operations order for a subordinate to reach and defend the location 777772727 by 8:30 A.M. on the first day of the war.

- Format:

```
OP ORDER  :  "ATTACK OR DEFEND" OBJECTIVE "Hex Location"
                EFFECTIVE TIME "DHHMM"
```

(2) Status reports from a unit to his commander.

(a) There are three types of status report: period, mission accomplishment, and situation demanded.

- Periodically, a unit will send a status report to his commander to inform him of his present location and the compass direction (i.e., north(N), south(S), etc.) in which he is headed
- Sample output:

```
STATUS REPORT: BLU 31 MECHBN LOCATED 77777264 HEADING S
```

This is a status report from the BLUE 31st Mechanized Battalion informing his commander that he is presently located at hex 77777264 heading south.

- Format:

```
STATUS REPORT:  "side" "Unit Name" LOCATED "Hex
                Location" HEADING "Direction"
```

(b) Whenever a unit reaches its objective the commander will be informed so that the progress of the battle can be monitored

- Sample output: STATUS REPORT: BLU 42 RECBN REACHED OBJ 77777246

This is a status report from the BLUE 42nd Reconnaissence Battalion informing his commander that he has reached the objective at hex 77777246.

- Format:

```
STATUS REPORT:  "Side" "Unit Name" REACHED OBJ
"Hex Location"
```

(c) Whenever a unit perceives the death or total destruction of another unit, it sends a "situation demanded" status report to his commander to inform him of the fact.

- Sample Output:

```
STATUS REPORT:  BLU 721 ARMCO DIED IN HEX 777772651
```

This is a status report stating that the BLUE 721st Armored Company was seen to be destroyed in hex 777772651.

- Format:

```
STATUS REPORT:  "Side" "Unit Name" DIED IN HEX "Hex
                Location"
```

(3) Artillery support request from a unit to an artillery battalion

- When a unit gets into combat he will request his general support artillery battalions to provide indirect artillery fire against an area where enemy units are located.
- Sample output:

```
ARTY REQUEST  :  SHOOT AT - 777772665
```

This is a support request for indirect artillery fire against enemy units located at hex 777772665.

- Format:

```
ARTY REQUEST  :  SHOOT AT - "Hex Location"
```

(4) Intelligence report from a unit to his commander

- When a unit sees an enemy unit, he will send a report to his commander informing him of the size, type, location, and movement direction of the enemy unit.
- Sample output:

```
INTEL REPORT  :  RED TKBN LOCATED 77777256 HEADING W
```

This is an intelligence report to the unit's commander informing him that the unit has sighted a RED tank battalion which is presently located at hex 77777267 and heading in a westerly direction.

- Format:

```
INTEL REPORT:  "Side" "Unit Type" LOCATED "Hex Location"
               HEADING "Compass Direction"
```

(5) Close air support request from a unit to the corps airbase

- When a unit is in combat, he will request close air support against an area in which enemy units are located.
- Sample output:

  ```
  CAS REQUEST  : ATTACK ENEMY UNIT AT - 777772667
  ```

  This is CAS request for supporting fire at hex 777772667.
- Format:

  ```
  CAS REQUEST  : ATTACK ENEMY UNIT AT - "Hex Location"
  ```

4.4.3 Sender Location and Transmission Time

The location of the sender and time of initiation of transmission are both displayed for each message

- Sample output:

  ```
  SENT FROM UNIT AT HEX 77777631 AT TIME 10051
  ```

  The sender of this message was located in hex 77777631 at 10051 when he sent the message. The time is in the DHHMM format. (DHHMM format is explained in section 4.4.1(1) above).
- Format:

  ```
  SENT FROM UNIT AT HEX "Hex Location" AT TIME "DHHMM"
  ```

4.5 SIGNAL INTELLIGENCE

TRACE is presently designed to simulate Red SIGINT operations against Blue communication networks. A listing of all Blue messages intercepted by Red listening units is made at the end of each simulation run. For each intercepted message, there is a summary of the characteristics of the communication net over which the message was transmitted. In addition, a list of the message contents (if known) and any direction finding information are listed. Figure 25 is a sample of the SIGINT information output.

```
/ TIME/   FREQ    / MODE/SECUR/      NET     //      SENDER      //   RECEIVER    //
 DHHMM   (MHZ)          LEVEL

/10048/ 55.750 MHZ/VOICE/CLEAR/NET: BDE ARTY //FROM: 21  MECHBN //TO: 41  ARTYBN //
                ARTY REQUEST : SHOOT AT - 777776371
                DF FIX       : SENDER LOCATED AT 777772442

/10048/ 15.272 MHZ/VOICE/CLEAR/NET: COR CAS  //FROM: 21  MECHBN //TO:  5  CORPS  //
                CAS REQUEST  : ATTACK ENEMY UNIT AT - 777776371

/10049/ 56.950 MHZ/VOICE/CLEAR/NET: BDE ADMIN//FROM: 42  ARTYBN //TO:  4 DIVARTY //
                STATUS REPORT: BLU  42  ARTYBN LOCATED  77777242 HEADING SSE

/10050/ 55.750 MHZ/VOICE/CLEAR/NET: BDE ARTY //FROM: 24  ARMBN  //TO: 43  ARTYBN //
                ARTY REQUEST : SHOOT AT - 777772642
                DF FIX       : SENDER LOCATED AT 777772435

/10051/ 44.050 MHZ/VOICE/CLEAR/NET: BDE INTEL//FROM: 21  MECHBN //TO:  2  ARMBDE //
                INTEL REPORT :RED   TKCO   LOCATED 777776375 HEADING WSW
                DF FIX       : SENDER LOCATED AT 777772442

/10051/ 55.750 MHZ/VOICE/CLEAR/NET: BDE ARTY //FROM: 24  ARMBN  //TO: 43  ARTYBN //
                ARTY REQUEST : SHOOT AT - 777772642
```

Figure 25. Example SIGINT output.

4.5.1 Communication Network Characteristics

For each intercepted message, there is a line of output providing all known characteristics of the communication net. The following is a list and explanation of these characteristics:

(1) Time at which message was intercepted.

- Time is presented in the standard form used in this simulation: in days, hours, and minutes (DHHMM) - one digit for the day of combat, two digits for the hour, and two digits for the minute. For example, the time 10629 represents 6:29 A.M. on the first day of combat.

(2) Transmission frequency of communication net - in megahertz (MHZ).

(3) Transmission mode of the communication net.

- VOICE, teletype (TTY), or facsimile (FAX).

(4) Security level of the message. For the present "CLEAR" will be printed.

(5) Net command level and traffic type.

- This information is provided only if message was transmitted in the clear.
- Command level refers to echelon of the net control station:

Corps	(COR)
Division	(DIV)
Brigade	(BDE)
Battalion	(BN)

- Net traffic type corresponds to the normal type of message sent over this net:

Command Net	(CMD)
Administrative Net	(ADMIN)
Artillery Request Net	(ARTY)
Intelligence Report Net	(INTEL)
Close Air Support Request Net	(CAS)
Messenger (no net was available)	(MSNGR)

(6) Sender and receiver of message.

The unit number and unit type of sender and receiver are listed. For example, if the 31st Mechanized Battalion had sent a message to the 3rd Armored Brigade, the sender and receiver portion of the intercept output would be:

```
//FROM:        31 MECHBN        //TO:      3 ARMBDE//
```

The following is an example of intercept resulting from a message transmitted by voice at 15.272 megahertz over the Corps Close Air Support Request Net from the 31st Mechanized Battalion to the 5th Corps.

```
/10629/ 15.272 MHZ/VOICE/CLEAR/NET:  COR CAS //FROM:  31 MECHBN //TO:  5 CORPS//
```

4.5.2 Message Content

The message content is displayed in the same fashion as that for the BLUE Message File. See section 4.4.2 above for a detailed explanation.

4.5.3 Radio Direction Finding Information

As messages are transmitted over the BLUE communication networks, RED radio direction finding units attempt to determine the locations of the senders of these messages. If a successful DF fix is made on a message sender, the location of the communication equipment is listed along with any network and content information obtained from this message.

- Sample output:

  DF : SENDER LOCATED AT 777772245

  DF information obtained from an intercepted message indicates that a message was transmitted from communication equipment located at 777772245; the frequency of the message, sender, receiver, etc., would be indicated in the network characteristics and message content lines.

- Format:

  DF FIX : SEN^ER LOCATED AT "Hex Location"

4.6 POST PROCESSOR OUTPUTS

This section will also define the inputs or user directives needed to request each type of output. User directives may be in any quantity and in any order. However, the greatest efficiency is gained when the time points used in one output do not overlap those used in the next.

An important concept throughout the outputs is that of the "time-interval". Every display is requested in relation to intervals rather than times. The interval between data points is fixed at the time of the TRACE simulation execution.

4.6.1 Message Tables

The message table is a ten-column table displaying information on each of the messages. An example appears in Figure 26. For each message type there are 12 entries.

(1) Number transmitted: After the name of the message type is displayed, the number of messages of that type transmitted during the interval ending at the time displayed in column heading.

(2) Number transmitted via a command net (Similar to #1).

(3) Number transmitted via an administrative net. (Similar to #1).

(4) Number transmitted via an artillery net. (Similar to #1).

(5) Number transmitted via an intelligence net. (Similar to #1).

(6) Number transmitted via a CAS net. (Similar to #1).

(7) Number transmitted by a courier. (Similar to #1).

(8) Number of messages transmitted in the interval that were intercepted (by either side.)

(9) Number of messages whose sender was located by enemy direction finding (DFed)

(10) Number of messages whose sender was attacked by indirect artillery fire after they were DFed.

(11) Average transmission time per messages (TOT-TOR) in seconds.

(12) Average message processing time (TOS-TOR) in seconds.

The directive to display this output is in the form:

```
Card Column --- 123   7        16
                OWIIXXTTTTTTTTTT
```

```
           MESSAGE TABLE

          SIDE=BLUE

TIME (IN HOURS)            0.00        .25        .50        .75
*******************************************************************
*                  *
*    NEW ORDERS    *         0.         2.        11.         6.
*      COMMAND NT  *         0.         2.         8.         1.
*      ADMIN NET   *         0.         0.         1.         1.
*      ARTY NET    *         0.         0.         1.         2.
*      INTEL NET   *         0.         0.         1.         2.
*      CAS NET     *         0.         0.         0.         0.
*      COURIER     *         0.         0.         0.         0.
*      INTERCEPTD  *         0.         1.         2.         2.
*      D.F.-ED     *         0.         0.         0.         1.
*      DF + ATKED  *         0.         0.         0.         1.
*      AVG XMSN T  *         0.       120.       125.       126.
*      AVG MSG T   *         0.       210.       370.       456.
*                  *
```

Figure 26. Example message table output.

where O is the type of output and appears in column 1. In this case the entry will be "M" to signify the message table.

W is which side the data is to be for. It will be "R" for RED message data (not implemented at this time) and "B" for BLUE.

II is the inter-interval display lapse. It is an integer asking for every nth interval to be displayed (up to 10 on one table): e.g., 02 displays every second interval. There is no summing between intervals. If insufficient intervals exist, the right most will be blank.

XX are columns to be ignored for this output type.

TTTTTTTTTT is a 10 place real number with no assumed decimals. It gives the time point (in seconds) which is to comprise the first table of the output. If exactly this time point is not on the file, the first one greater will be used.

Each message table generates exactly two pages.

4.6.2 Unit Status Tables

The unit status tables are ten column tables, each two pages long. Eight units are displayed on each table and as many tables as necessary are generated to display all the units requested by the user. An example of this table appears in Figure 27. Note the last entry, the 73rd Armored Cavalry Team, gets killed between hours 2 and 3. The "DEAD" message is used for any unit that does not yet exist or ceases to exist.

Thirteen entries are made for each unit at each interval. These represent the status of the unit at that instant. The first entry for each is the unit number and the second is the unit type. Together these two identify the unit. The top entry in Figure 27 is for the 911th Battery which is a battery of 122mm guns. The third entry is the hex location of the unit. The remaining entries give the quantity on hand of each material type.

```
       UNIT STATUS TABLE

      SIDE=RED                          SMALLEST UNIT DISPLAYED=SECTION
TIME (IN HOURS)          1.00        2.00        3.00        4.00        5.00
********************************************************************************

*   UNIT NUMBR    *          911.        911.        911.        911.        911.
*   UNIT NAME     *   BTY122      BTY122      BTY122      BTY122      BTY122
*   HEX POSITN    *   777761572.  777761575.  777761575.  777761575.  777761575.
*   INFANTRY      *            1.          1.          1.          1.          1.
*   ARMOR         *            0.          0.          0.          0.          0.
*   ARTILLERY     *            6.          6.          6.          6.          6.
*   ROCKETS       *            0.          0.          0.          0.          0.
*   GRND NUKES    *            0.          0.          0.          0.          0.
*   AIR NUKES     *            0.          0.          0.          0.          0.
*   AA            *            0.          0.          0.          0.          0.
*   AG            *            0.          0.          0.          0.          0.
*   DUAL AA       *            0.          0.          0.          0.          0.
*   AMMUNITION    *          435.        390.        390.        390.        390.
*                 *
*   UNIT NUMBR    *            7.          7.          7.          7.          7.
*   UNIT NAME     *   ACS           ACS        ACS          ACS        ACS
*   HEX POSITN        77777633.    77777264.  77777242.    77777242.  77777242.
*   INFANTRY      *            7.          6.          1.          1.          1.
*   ARMOR         *            0.          0.          0.          0.          0.
*   ARTILLERY     *            0.          0.          0.          0.          0.
*   ROCKETS       *            0.          0.          0.          0.          0.
*   GRND NUKES    *            0.          0.          0.          0.          0.
*   AIR NUKES     *            0.          0.          0.          0.          0.
*   AA            *            0.          0.          0.          0.          0.
*   AG            *            0.          0.          0.          0.          0.
*   DUAL AA       *            0.          0.          0.          0.          0.
*   AMMUNITION    *            0.          0.          0.          0.          0.
*                 *
*   UNIT NUMBER              73.         73.          0.          0.          0.
*   UNIT NAME         ACT         ACT         DEAD        DEAD        DEAD
*   HEX POSITN    *   777761563.  777761563.          0.          0.          0.
*   INFANTRY      *            3.          3.          0.          0.          0.
*   ARMOR         *            0.          0.          0.          0.          0.
*   ARTILLERY     *            0.          0.          0.          0.          0.
*   ROCKETS       *            0.          0.          0.          0.          0.
*   GRND NUKES    *            0.          0.          0.          0.          0.
*   AIR NUKES     *            0.          0.          0.          0.          0.
*   AA            *            0.          0.          0.          0.          0.
*   AG            *            0.          0.          0.          0.          0.
*   DUAL AA       *            0.          0.          0.          0.          0.
*   AMMUNITION    *          141.        251.          0.          0.          0.
```

Figure 27. Example unit status table output.

At the top of the table are two important entries. The first, SIDE, tells which side's units are being displayed. The second, SMALLEST UNIT DISPLAYED, shows the lowest level unit that can appear on this table. In the example, the table shows RED units and no unit lower than section will be displayed. (Actually there are no sections or platoons so company is the lowest that actually appears.)

The directive to display this output takes the form:

```
Card Column --- 123 5 7         16
                OWIILLTTTTTTTTTT
```

where 0,W,II, and TTTTTTTTTT are the same as for the message table output, except that "U" will be used for 0 to signify the unit status table.

LL is an integer number that indicates the level of the lowest unit that is permitted on this set of tables.

Unit tables will continue to be generated until all unit, of the appropriate level, on the chosen side have been displayed once. Each table except the last one generates exactly two pages. The final one will be as short as necessary.

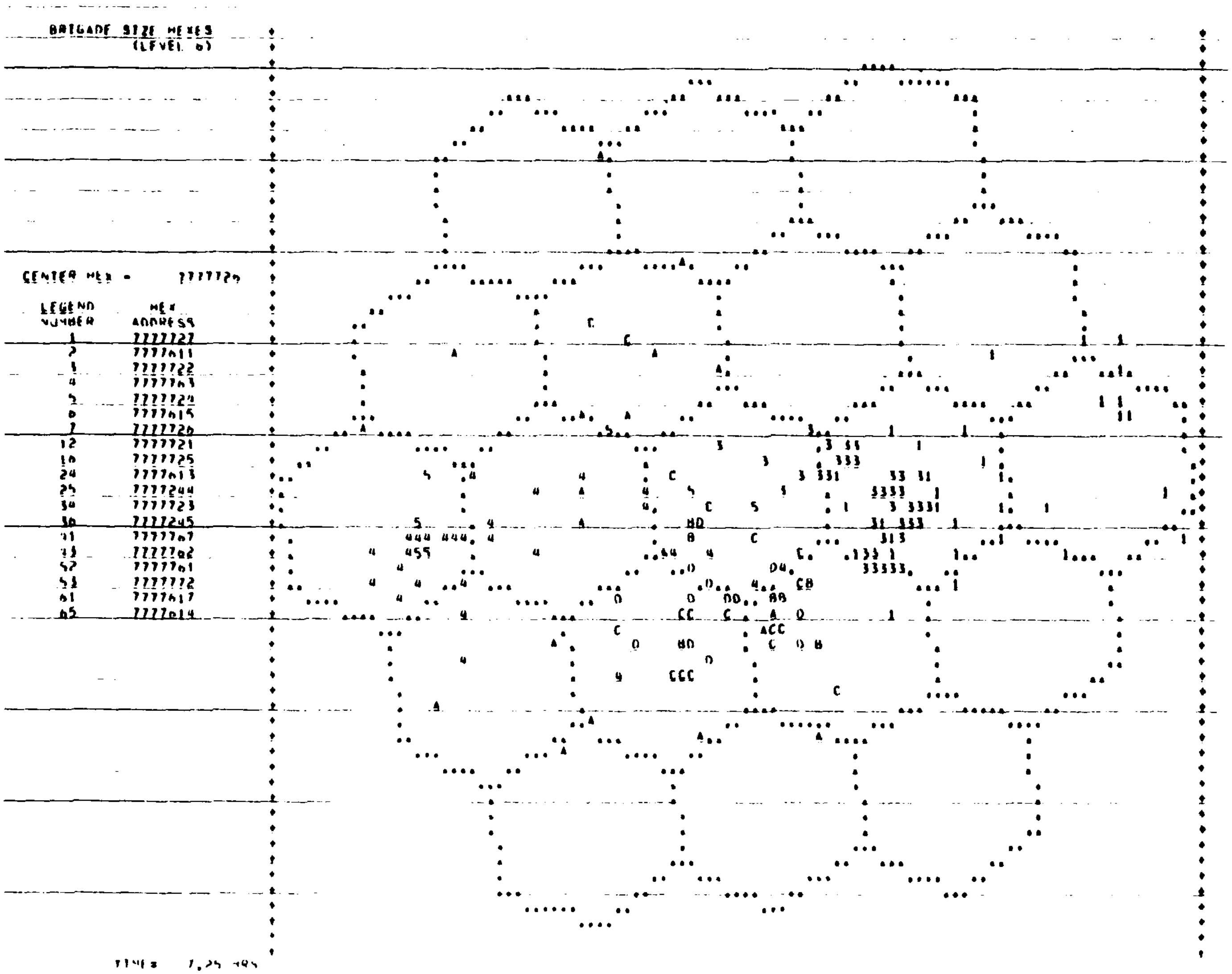
4.6.3 Snapshot Maps

Figure 28 shows an example of a snapshot map. Each set of maps is accompanied by a legend as shown in Figure 29. This legend relates each hex pictured with a hex address listed at the left of the diagram.

The map shown in Figure 28 is in one of four possible formats. These formats are:

RXB All Red units are signified by an "R", Blue units by a "B" and where ever units of the two sides are colocated an "X" is used. When units of the same side are colocated only one symbol is displayed

RB Similar to the RXB format only whenever units are colocated, successive units are placed in empty adjacent point positions regardless of which side they belong to. When all 8 adjacent locations have been filled, additional colocated units are simply left off the map.



BRIGADE SIZE HEXES
(LEVEL 6)

CENTER HEX = 7777726

LEGEND NUMBER	HEX ADDRESS
1	7777727
2	7777611
3	7777722
4	7777763
5	7777724
6	7777615
7	7777726
12	7777721
16	7777725
24	7777613
25	7777244
34	7777723
36	7777245
41	7777767
43	7777762
52	7777761
53	7777772
61	7777617
65	7777614

TIME = 7.25 HRS

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Figure 28. Snapshot map

```
BRIGADE SIZE HEXES
        (LEVEL 6)

CENTER HEX =     7777720

 LEGEND        HEX
 NUMBER      ADDRESS
     1       7777727
     2       7777611
     3       7777722
     4       7777763
     5       7777724
     6       7777615
     7       7777726
    12       7777721
    16       7777725
    24       7777613
    25       7777244
    34       7777723
    36       7777245
    41       7777707
    43       7777762
    52       7777761
    53       7777772
    61       7777617
    65       7777614
```

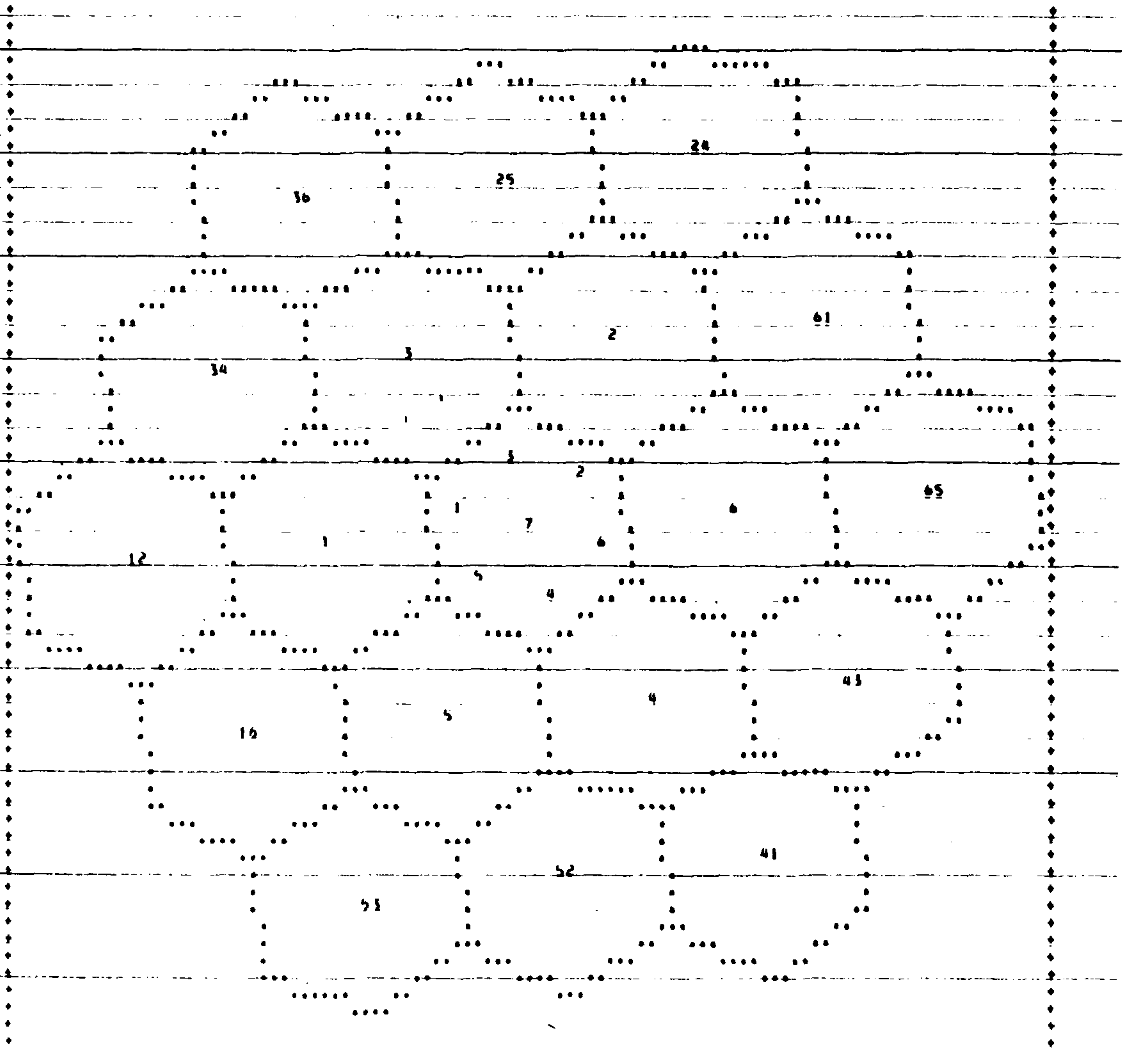

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Figure 29. Map legend

IXA This is the same as the RXB format only the letters A-F are used to differentiate the type of Blue unit being displayed and 1-6 for Red. A legend as shown in Figure 30 is displayed for this. When units of the same side are colocated only one is displayed.

IA This is the same as the RB using the display scheme of the IXA. Figure 28 is in IA format.

Snapshot maps are produced over a range of times. Each map requires exactly one page. An additional page is used for the legend to accompany the series. The directive to display this output is in the form:

```
Card Column                1         2 2           44
            123 5 7         7         7 9           12
            OFIILLTTTTTTTTTTEEEEEEEEEENNCCCCCCCCCCCCHH
```

where 0, II and TTTTTTTTTT are the same as for the message table, except that "P" will be used for 0 to signify the snapshots; LL is the same as for the unit table.

F is the format choice: 1=IA, 2=IXA, 3=RB, and 4=RXB.

EEEEEEEEEE is a 10 place real number with no assumed decimals which gives the time point of the last of the series of snapshots

NN is the number of hexes to be displayed. There are two choices: 7 or 19. Figure 28 shows 19 hexes. Had the choice for that output been 7, only the seven center hexes of the map would have been displayed. However, the map would have been enlarged so that those seven hexes would fill the same area on the page.

CCCCCCCCCCCC is a right justified integer hex address. This is the address of the hex that is to be in the center of the map.

HH is the level of the hexes that are to be displayed.

4.6.4 Unit Trace Maps

Unit trace maps are exactly like snapshot maps except that only one unit appears on it. The units first position is designated by an "A", the second by a "B", etc. If there are more than 26 positions, the 27th will begin at "A" again. This map will be dynamically placed so that the center hex will be that hex that the unit was in most often. A legend, as in Figure 29, will accompany the map. The directive for this output is in the form:

```
Card Column                 1         2 2           4 4   4     5
            123 5 7         7         7 9           1 3   7     3
            OWIIAATTTTTTTTTTXXXXXXXXXXNNXXXXXXXXXXXXHHUUUUDDDDDDD
```

where O, W, II, and TTTTTTTTTT are the same as for the message table, except that "T" will be used for O to signify the unit trace;

AA is the level of the hex/address to be used for positioning the unit on the trace map;

NN and HH are the same as for the snapshot maps. Note that there is no endtime specified. Unit traces maps always extend to the end of the file;

UUUU is a integer giving the unit number. If the 121st tank company was to be traced, the unit number would be 121;

DDDDDDD is the name of the unit. Permissible names are (Δ represents a blank) shown below:

Level 3 units: ΔΔACTΔΔ
ΔARMCOΔ
ΔΔTKCOΔ
ΔBTY152
ΔBTY122
ΔBTY175
ΔBTY155

	ΔMRLBTY
	ΔΔHHTΔΔ
	ΔΔHHBΔΔ
	ΔΔHHCΔΔ
	ΔRECCOΔ
	ΔΔMRCOΔ
	ΔMECLOΔ
	COMPANY
Level 4 units	ΔΔTKBNΔ
	ΔARTYBN
	ΔMRLBNΔ
	ΔARMBNΔ
	ΔRECBNΔ
	ΔΔACSΔΔ
	ΔΔMRBNΔ
	ΔMECHBN
	ΔΔBTNΔΔ
Level 5 units	ΔARMBDE
	ΔΔACRΔΔ
	ΔTKRGTΔ
	ΔMRRGTΔ
	ΔDISCOM
	ΔRECRGT
	ARTYRGT
	DIVARTY
	BDE/RGT
Level 6 units	ΔARMDIV
	MECHDIV
	ΔTKDIVΔ
	ΔCOSCOM
	CORARTY
	ΔΔDIVΔΔ
Level 7 units	TKΔARMY
	ΔCORPSΔ

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TRACE COMPUTER MODEL USER'S GUIDE.(U)

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UNCLASSIFIED BDM/W-78-776-TR DNA-4351T-2D NL

2 of 2

AD A079946

END

DATE FILMED

3-80

DDC

```
THE FOLLOWING ARE SNAPSHOTS FROM             0 TO     36000.
OF EVERY  1 TIME POINTS

 3 LEVEL UNITS ARE DISPLAYED
                    SYMBOLS
                  BLUE   UNIT   RED
                    A     HQ     1
                    B     INF    2
                    C     ART    3
                    D     TNK    4
                    E     REC    5
                    F    MISC    6
```

Figure 30. Symbol legend for snapshot maps.

4.7 Directives

A display of the four directive forms appears in Figure 31. Due to the nature of the input means, card positions not carrying data must be left blank.

```
------------------ Card Columns ---------------------
         11111111112222222222333333333344444444445555
12345678901234567890123456789012345678901234567890123
-----------------------------------------------------

OWIIXXTTTTTTTTTT                                      Message Table

OWIILLTTTTTTTTTT                                      Units Status Table

OFIILLTTTTTTTTTTEEEEEEEEEENNCCCCCCCCCCCCHH            Snapshot Map

OWIIAATTTTTTTTTTXXXXXXXXXXNNXXXXXXXXXXXXHHUUUDDDDDDDD Unit Trace Map
```

Figure 31. Summary of post processor directive formats.

APPENDIX A
USER GUIDE TO HEXAGONAL COORDINATE SYSTEM

A.1 INTRODUCTION

The purpose of this appendix is to give a brief explanation of the Hexagonal Coorcinate System (HECS) used in TRACE. For a more detailed discussion, including the rationale for using this coordinate system, the reader is referred to the draft technical report, "An Integrated Coordinate System for Combat Modeling", BDM/W-78-297-TR, 19 May 1978.

A.2 STRUCTURE OF HECS

The Hexagonal Coordinate System is based upon the concept of tiling the plane with a grid of regular hexagons and aggregating them into successively larger clusters of 7. A single regular hexagon in the grid is called a level 0 hex. A cluster of 7 level 0 hexes, one regular hexagon together with its 6 neighboring hexagons, is called a level 1 hex. This process of aggregation can be iterated, and in general a cluster of 6 level n hexes surrounding a central level n hex forms a level n + 1 hex.

The higher level hexes are not true regular hexagons, but they remain approximately hexagonal in shape. Hexes at any level mesh together to tile the plane.

A.3 THE TRACE BATTLEFIELD

The TRACE simulation runs on a battlefield represented by a single level 12 hex. This hex contains 7 level 11 hexes, each of which contains 7 level 10 hexes, and so on down to the level 0 hexes, which are regular hexagons. The grid is oriented so that the level 0 hexes have a pair of opposite edges running west to east. The scale of the battlefield is determined by the size of the level 0 hexes, which are approximately 72.89 meters across (from one side to the opposite side).

Each unit in TRACE is located in a hex of a certain level. Units at higher levels of command occupy more territory and are placed in larger hexes. Table 2 shows the various command levels and the dimensions of the hexes which they occupy.

Table 2. Hexes typically occupied by various command levels.

Command Level	Hex Level	Hex Diameter	Hex Area
Company	3	1.35 km	1.6 km^2
Battalion	4	3.57 km	11.0 km^2
Brigade/Regiment	5	9.45 km	77.3 km^2
Division	6	25.00 km	541.3 km^2
Corps	7	66.14 km	3788.9 km^2

A.4 HEX ADDRESSES

A hex address is a string of one to twelve digits which identifies a specific hex. It is a way of encoding both the location and the level of a hex. Each digit in a hex address is from 1 through 7 inclusive. The leftmost digit identifies which of the 7 level 11 hexes contains this hex. If there are no further digits, then the hex address corresponds to this level 11 hex. The next digit identifies which of the 7 level 10 hexes comprising the level 11 hex contains the hex in question. This classification procedure continues all the way down to the level of the specified hex. The hex address of a level 0 hex will have 12 digits, and in general the following equation is satisfied:

$$L + D = 12$$

where L is the level of the hex and D is the number of digits in his hex address.

It remains to describe which hex is given which number in a cluster of 7 hexes. The numbering scheme for a level 1 cluster of 7 level 0 hexes is shown in Figure 32. Note that 7 indicates the center hex and 1 indicates the hex directly north of center. The rest of the numbering scheme is chosen for computational convenience. The numbering scheme for a level 2 cluster of 7 level 1 hexes is shown in Figure 33. The scheme is essentially the same except that there has been a slight counterclockwise

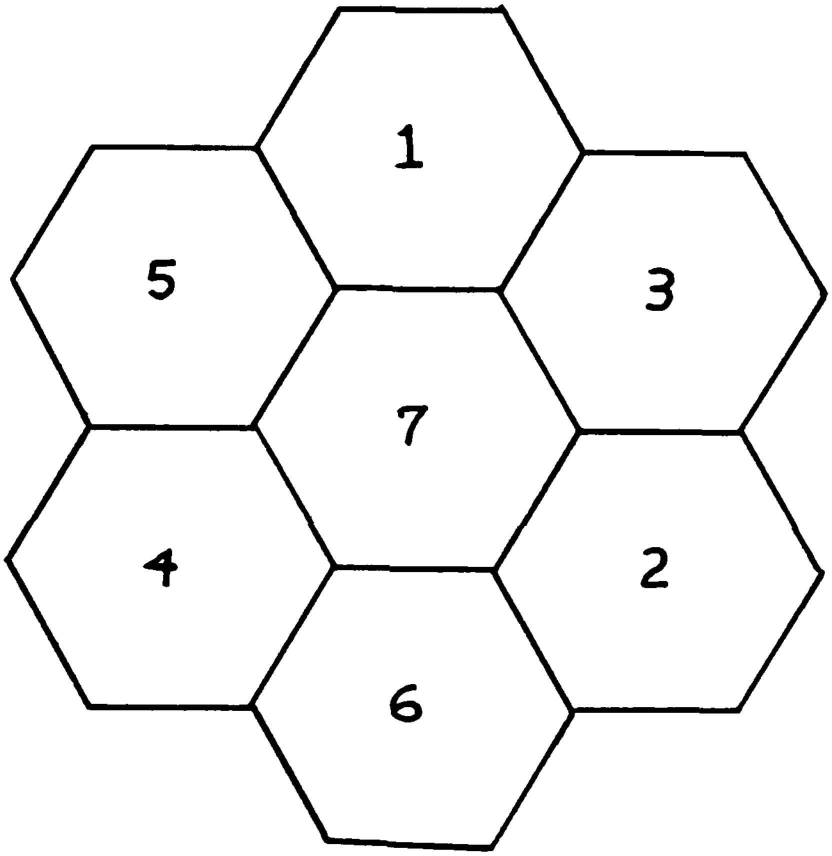

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Figure 32. Numbering scheme for level 0 hexes within a level 1 cluster.

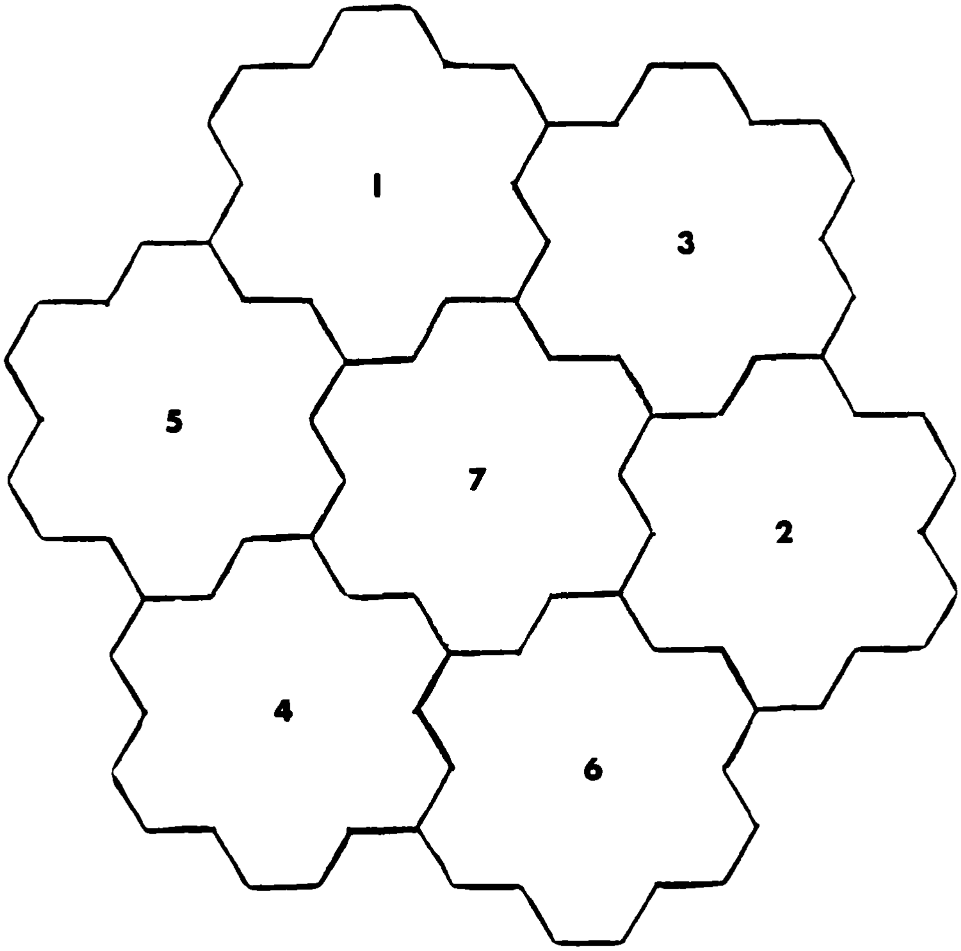

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Figure 33. Numbering scheme for level 1 hexes within a level 2 cluster.

rotation of the positions of the hexes numbered 1 through 6. For clusters of higher and higher level hexes, the same numbering scheme is used, but the relative positions of the outer hexes rotate approximately 19 degrees counterclockwise for each increase in level.

Figure 34 illustrates the combined numbering scheme for level 0 hexes within a level 2 hex. The two digits shown would be the last 2 digits in the hex addresses for these level 0 hexes. Note that the shaded level 0 hex is numbered 35 because it is in the 5 position within the number 3 level 1 hex in the level 2 cluster. Figure 35 shows a few sample hex addresses in a level cluster. Actually each address would be preceded by a string of 9 digits identifying the particular level 3 hex illustrated.

A.5 HEX DIRECTIONS

Units at a given level of command in TRACE occupy hexes of a given level as listed in Table 2. Movement is always in the direction of one of the six surrounding hexes of the same level. The directions are identified by the same numbering scheme as used for creating hex addresses. Thus, at each level, the hex direction 7 represents a null direction signifying no movement, and there are 6 equally spaced hex directions numbered 1 through 6. At level 0, hex direction 1 corresponds to north, but it undergoes a counterclockwise rotation of about 19 degrees for each higher level. Figures 36 through 40 illustrate the hex directions at levels 3 through 7, and Table 3 gives the corresponding approximate compass directions which appear in the running commentary and status summary outputs.

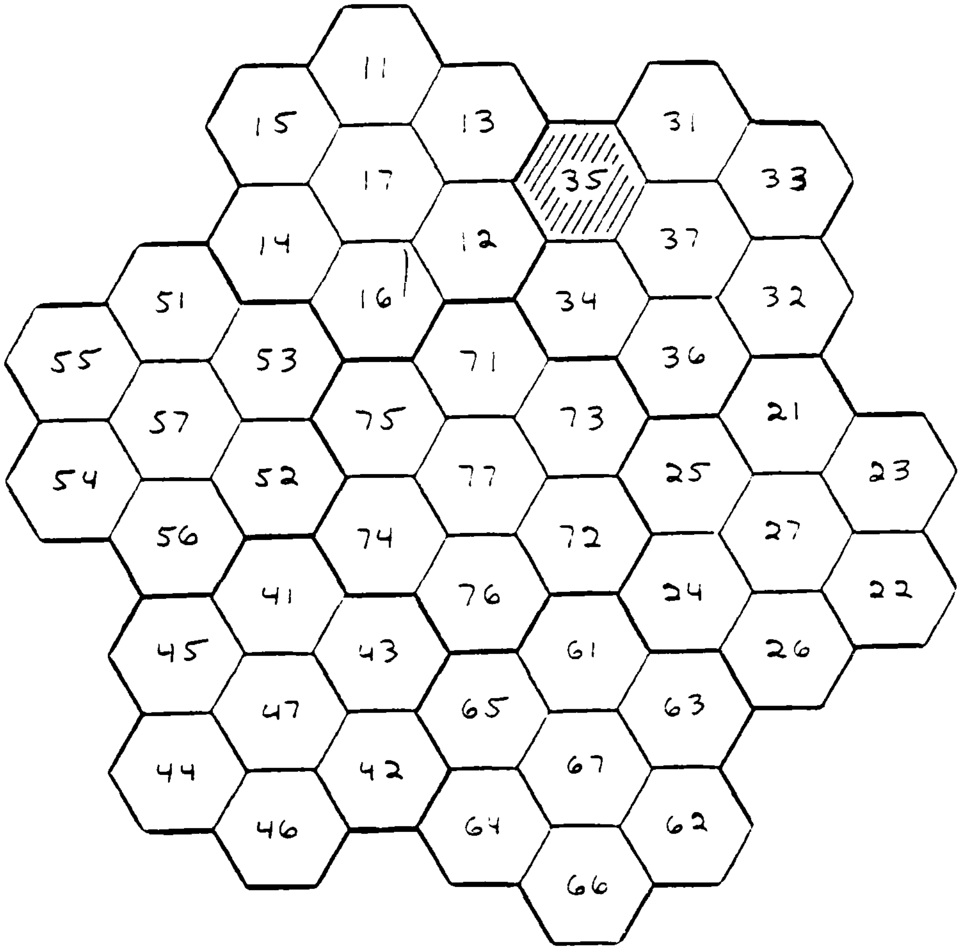

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Figure 34. Combined numbering scheme for level 0 hexes within a level 2 cluster.

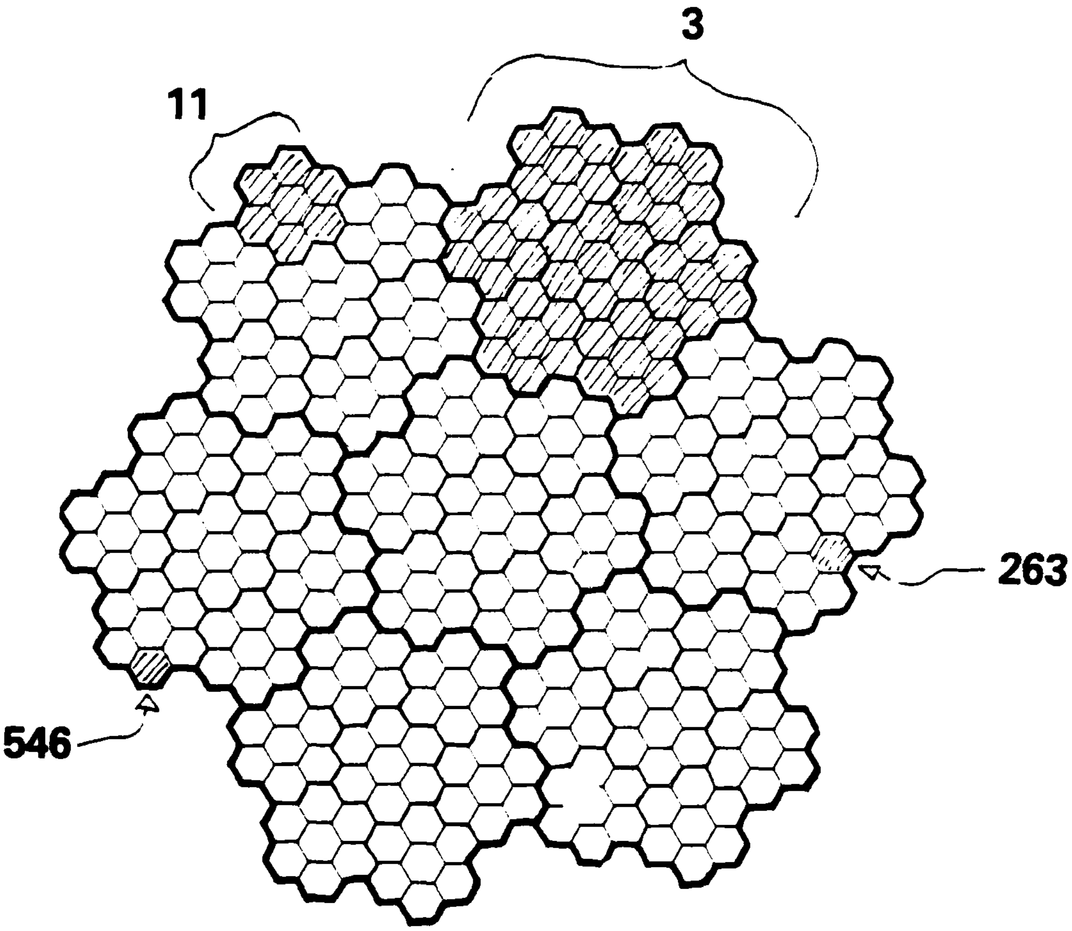

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Figure 35. Sample hex addresses within a level 3 cluster.

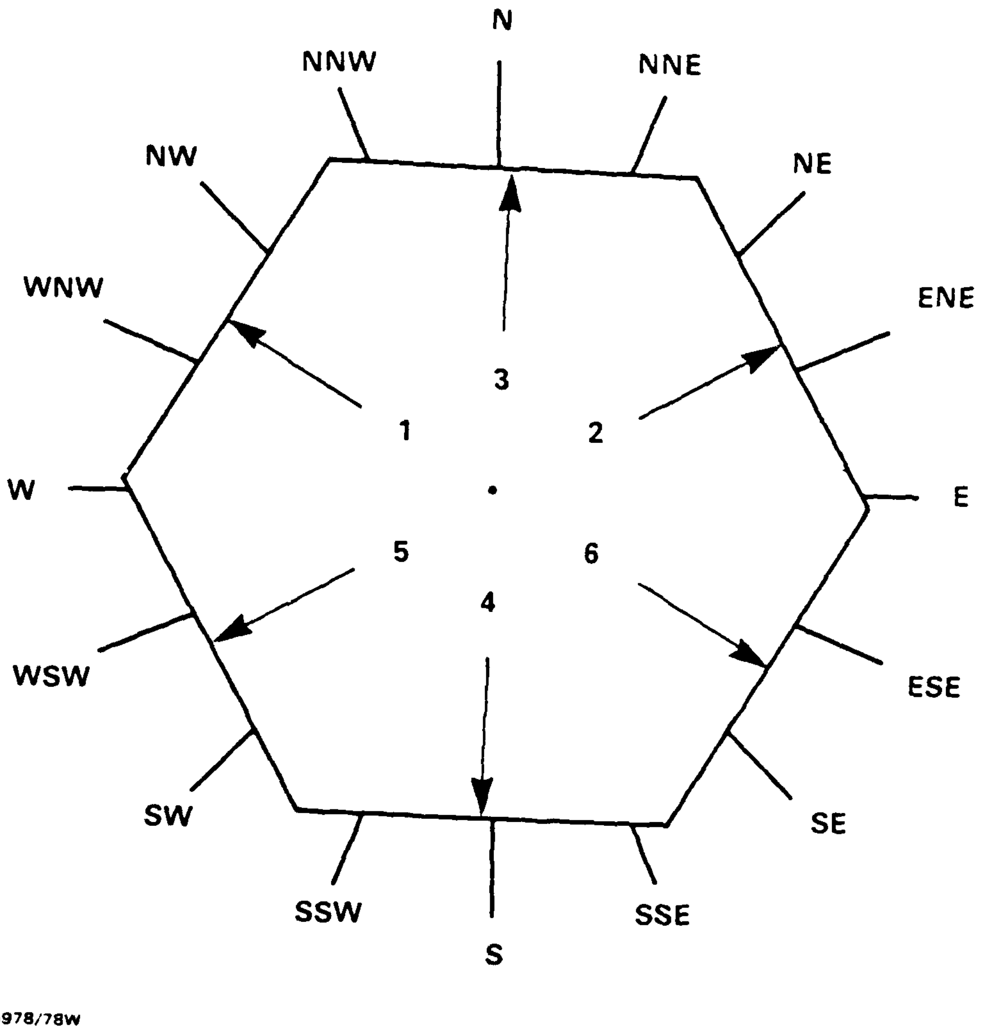

Figure 36. Hex directions at level 3.

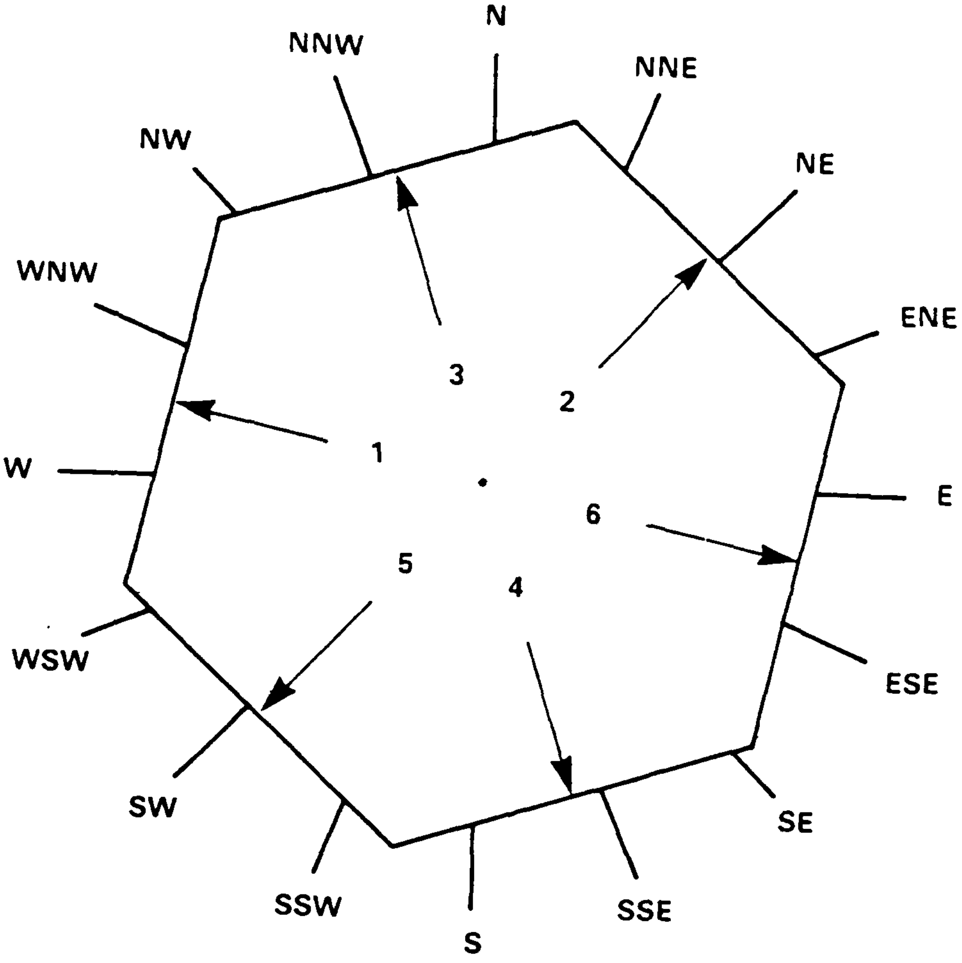

Figure 37. Hex directions at level 4.

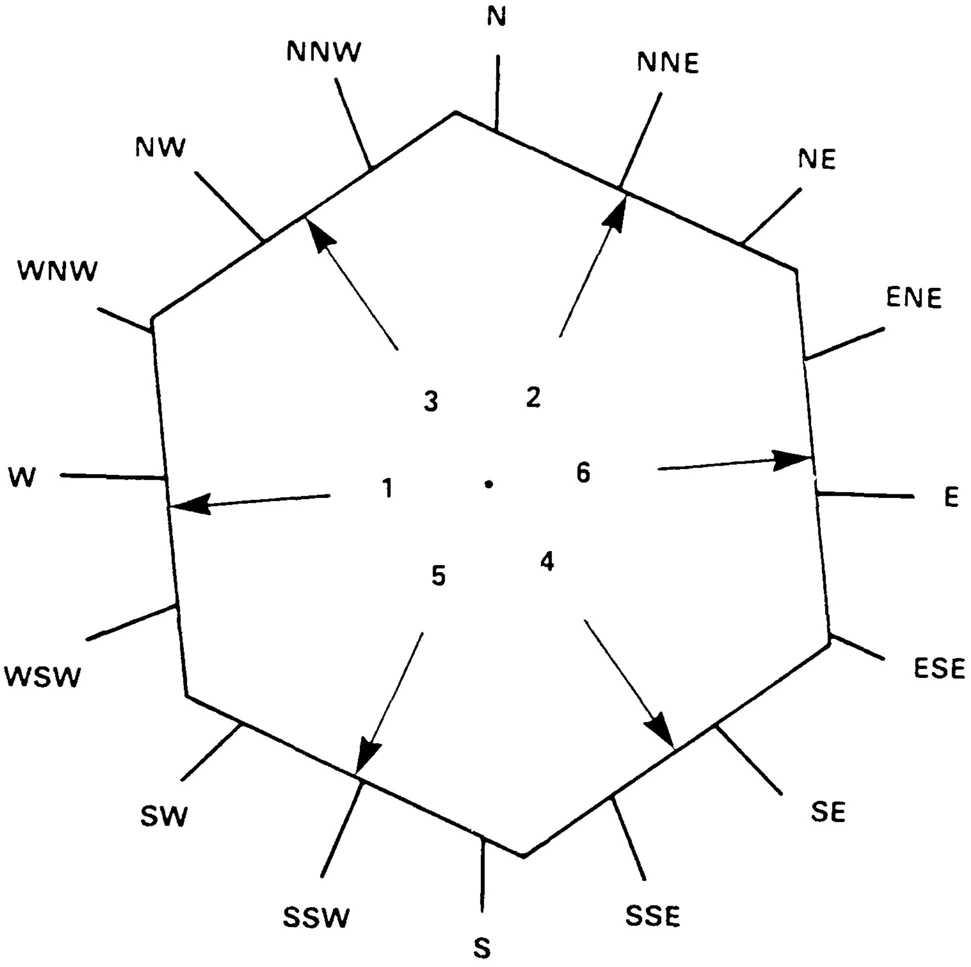

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Figure 38. Hex directions at level 5.

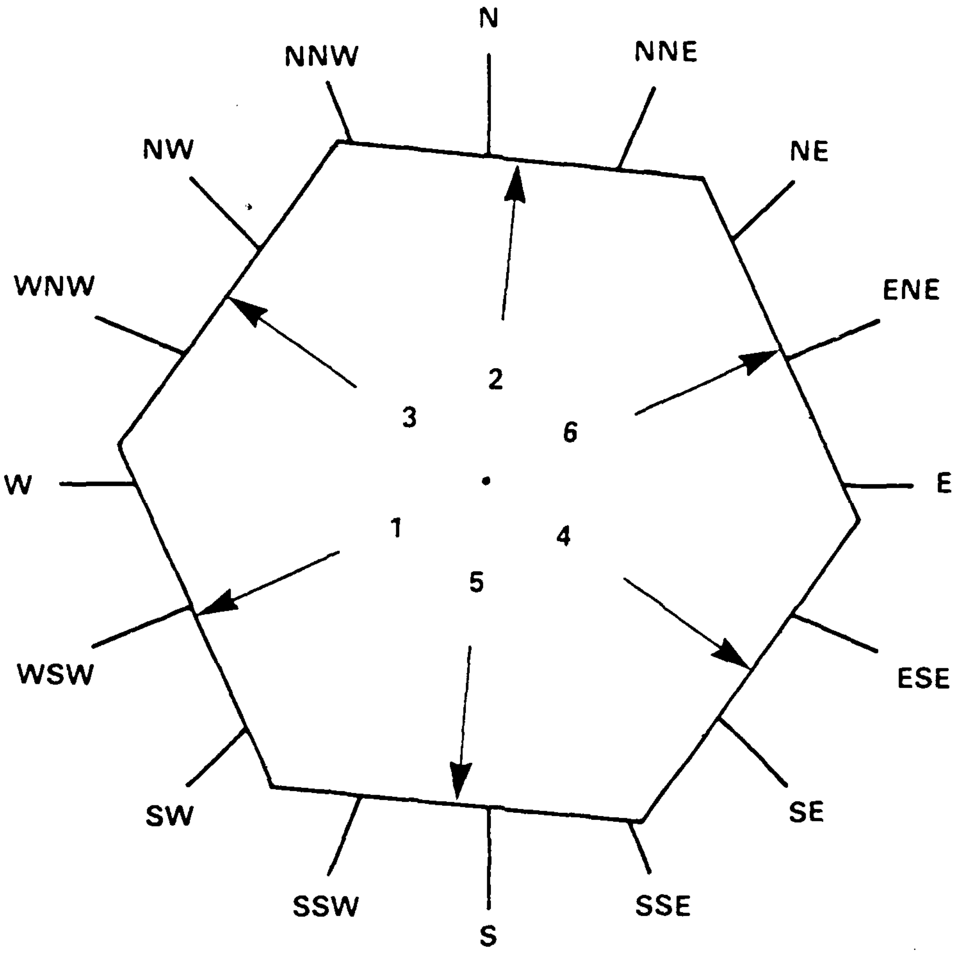

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Figure 39. Hex directions at level 6.

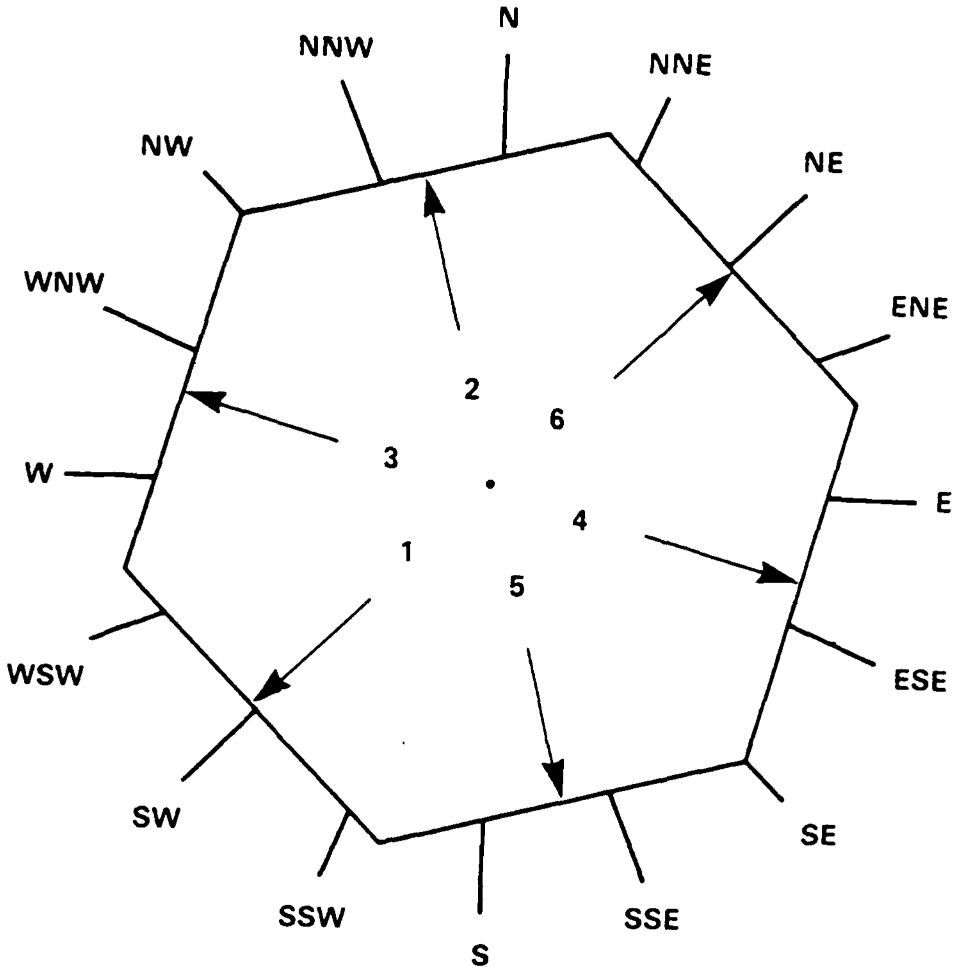

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Figure 40. Hex directions at level 7.

Table 3. Correspondence between hex directions and compass headings.

UNIT LEVEL	HEX LEVEL	HEX DIRECTIONS 1	3	2	6	4	5	7
CORPS	7	SW	WNW	NNW	NE	ESE	SSE	---
DIV	6	WSW	NW	N	ENE	SE	S	---
BDE/REG	5	W	NW	NNE	E	SE	SSW	---
BTN	4	WNW	NNW	NE	ESE	SSE	SW	---
CO	3	WNW	N	ENE	ESE	S	WSW	---

This chart provides:

a) Hex level occupied by various size units

b) Correspondence between hex directions (1-7) used for unit movement and approximate compass headings at various levels. (Note: hex directions are listed clockwise) Hexes at different levels have different rotations. For example, a corps moving in hex direction 1 between level 7 hexes would be moving roughly southwest. A company moving in hex direction 1 between level 3 hexes would be moving approximately west northwest.

APPENDIX B

EXPLANATION OF RUNNING COMMENTARY REMARKS

B.1 INTRODUCTION

A general description and some examples of the running commentary printed out during a TRACE simulation run are given in section 4.2. This appendix explains the meaning of the comments printed under the heading "REMARKS". In addition, the name of the subroutine which generates the output is noted in parentheses after each comment. All commentary messages are not displayed in response to all stimulus. Some are only displayed a percentage of the time. The current percentage is given in the parentheses along with the subroutine name. Due to the modular construction of the METRIC family of simulations and that blocks of code, developed by different teams, are often transported from one member to another; discrepancies in message abbreviations sometimes appear. In TRACE, COM and CMD are both used to refer to the command communications network.

B.2 LIST OF COMMENTS

1. ADMIN NET-BUSY W/BKD (O-NETOPEN)

This comment is printed when a unit is unable to transmit a message over an administrative net because the net is busy with a background message at that time. This is one of a series of comments which can apply to any one of 5 different types of nets:

ADMIN NET	Administrative net for status reports
ARTY NET	Artillery support request net
CAS NET	Close air support request net
COM NET	Command net for operations orders
INTEL NET	Intelligence reporting net

Also, there are 5 possible reasons for a net being closed:

BUSY W/MSG	Another message is currently being transmitted over this net.
BUSY W/BKD	Net is busy processing a background message. A background message is one that simulates normal net traffic. The percentage of time a net is busy with background is an input specified by the user.

INOPERABLE Either the receiver or sender communication equipment for this net has been damaged.

JAMMED Net transmission frequency is currently jammed.

OUT/RANGE Sender and Receiver are not within communication range of their equipment for this net.

2. ADMIN NETBUSY W/MSG (0-NETOPEN) See comment 1.

3. ADMIN NETINOPERABLE (0-NETOPEN) See comment 1.

4. ADMIN NETJAMMED (0-NETOPEN) See comment 1.

5. ADMIN NET-OUT/RANGE (0-NETOPEN) See comment 1.

6. ADMIN NET SEC BREAK (100-INTRCPT)

This comment will be printed when a future capability is implemented. It will have the following general form:

"net type" SEC BREAK

The possible net types are the same as those listed under comment 1. It will signify a security break on the net.

7. ADMIN NET-TRANSMIT (30-TRNSMIT)

This comment is printed periodically when a unit is transmitting a message over an administrative net. The general form of this type comment is:

"net type" - TRANSMIT

The possible net types are the same as those listed under comment 1.

8. ARRIVE AT OBJ (100-MOVMUZQ)

This comment is printed whenever a company level unit arrives at the objective specified in his operations order, if the unit is moving in a noncombat status. During the processing of this event the commander of the unit will determine if the company level unit should be given another objective to meet the commanding unit's phaseline requirements. (See comments 46, 50, 69, 96, 100.)

9. ARTILLERY CASUALTIES (100-GUNCON)

This comment is printed whenever a unit suffers casualties as a result of an indirect fire bombardment from an enemy artillery battery. Refer to the losses and on hand columns of the output for the latest status of the unit receiving the casualties.

10. ARTY NET-BUSY W/BKD (0-NETOPEN) See comment 1.

11. ARTY NET-BUSY W/MSG (0-NETOPEN) See comment 1.

12. ARTY NET-INOPERABLE (0-NETOPEN) See comment 1.

13. ARTY NET-JAMMED (0-NETOPEN) See comment 1.

14. ARTY NET-OUT/RANGE (0-NETOPEN) See comment 1.

15. ARTY NET SEC BREAK (100-INTRCPT) See comment 6.

16. ARTY NET-TRANSMIT (30-TRNSMIT) See comment 7.

17. ATKER CONTINUES ADV (100-CBTFIR)

This comment is printed whenever a company decides to continue its advance when in combat, even though it has suffered casualties, has almost exhausted its ammunition, or is in danger of being overwhelmed by enemy forces. (See comments 19, 32, 43, 45, 99.)

18. AVOID COMBAT (100-MZENMUD)

A unit decides to avoid combat if it is an artillery unit, an electronic warfare unit, or a headquarters unit. When one of these type units observes an enemy unit moving nearby, and the unit is close enough, the artillery battery, EW company, or HHC will move away in order to avoid engaging in combat. (See comments 51, 88.)

19. BREAKS AND RUNS (100-CBTFIR)

This comment is printed when a unit decides not to continue combat and attempts to flee from combat as quickly as possible. This does not prevent enemy units from continuing to fire as long as the unit is within range. (See comments 17, 32, 43, 45, 99.)

20. BTRY HALTS TO FIRE (100-FDCHALT)

When a battalion fire direction center (FDC) receives an artillery request, it considers whether or not any of the batteries should stop to provide fire support. The FDC uses the backlog of requests on hand and the relative locations of the batteries as guidelines in choosing whether to stop a unit which is road marching. This comment is printed when a battery is chosen to stop and fire. (See comments 21, 47, 48, 94, 102, 103, 104.)

21. BTRY ROAD MARCH (100-FDCPACK)

This comment is printed when the FDC decides to move an artillery battery (BTRY) as a result of receiving an artillery request. (See comments 20, 47, 48, 94, 102, 103, 104.)

22. CAS CASUALTIES (100-CASDIE)

This comment is printed whenever a ground unit suffers casualties as a result of being attacked by enemy close air support (CAS). Refer to the losses and on hand columns of the output for the latest status of the unit receiving the casualties.

23. CAS INEFFECTIVE (100-CASDIE)

This comment is printed when close air support (CAS) does not cause any casualties to enemy forces. When a unit is attacked by CAS, either this comment or comment 22 is printed.

24. CAS NET-BUSY W/BKD (0-NETOPEN) See comment 1.

25. CAS NET-BUSY W/MSG (0-NETOPEN) See comment 1.

26. CAS NET-INOPERABLE (0-NETOPEN) See comment 1.

27. CAS NET-JAMMED (0-NETOPEN) See comment 1.

28. CAS NET-OUT/RANGE (0-NETOPEN) See comment 1.

29. CAS NET SEC BREAK (100-INTRCPT) See comment 6.

30. CAS NET-TRANSMIT (30-TRNSMIT) See comment 7.

31. CBT SPD OUT OF RANGE (100-CBTSPD)

This comment is printed when a company's combat speed first gets out of a prescribed range.

32. CEASE FIRE AND HOLD (10-CBTFIR)

This comment is printed when a unit runs low on ammunition and decides to hold its position. (See comments 17, 19, 43, 45, 99.)

33. COMBAT ADVANCE (100-HOWSMOV)

This comment is printed whenever a unit in combat advances into a hex toward its objective. Note that when a defending unit is moving away from attacking enemy units, toward its given objective, it is considered to be advancing, not retreating, since it is moving in its intended direction. (See comment 35.)

34. COMBAT LOSS (100-WARACES)

This comment is printed when a unit loses forces as a result of direct ground fire. Refer to the losses and on hand columns of the output to ascertain the present status of the unit.

35. COMBAT RETREAT (100-HOWSMOV)

This comment is printed when a unit is forced away from its intended hex as a result of losing forces in combat. At the present time this message is only applicable to attacking units which are actually retreating away from their intended objective. (See comment 33.)

36. COM NET-BUSY W/BKD (0-NETOPEN) See comment 1.

37. COM NET-BUSY W/MSG (0-NETOPEN) See comment 1.

38. COM NET-INOPERABLE (0-NETOPEN) See comment 1.

39. COM NET-JAMMED (0-NETOPEN) See comment 1.

40. COM NET-OUT/RANGE (0-NETOPEN) See comment 1.

41. COM NET SEC BREAK (100-INTRCPT) See comment 6.

42. COM NET-TRANSMIT (30-TRNSMIT) See comment 7.

43. CONTINUE COMBAT (100-CBTFIR)

This comment is printed when a unit decides to continue in combat despite casualties that the unit has suffered. (See comments 17, 19, 32, 45, 99.)

44. COURIER DELIVERY (0-DETMSG)

This comment is printed when a unit dispatches a courier to deliver a message that it has been unable to transmit to the intended receiver over any of its communication nets.

45. DISENGAGE-NO AMMO (100-MUZCMBT)

This comment refers to the actions taken by a unit when it effectively has no more ammunition and decides to disengage from combat, or at least attempt to disengage. (See comments 17, 19, 32, 43, 99.)

46. EXECUTE NEXT PHASE (100-MUZAMOV)

This comment is printed when a unit arrives at an intermediate objective and decides to continue on toward the next objective, whether it be its final objective or another intermediate one. The unit is in a non-combat move situation at this time, either moving cross country or moving along a road. (See comments 8, 50, 69, 96, 100.)

47. FDC OVERLOADED (100-FDCPASS)

This comment is printed whenever a fire direction center (FDC) has too many artillery requests backlogged to effectively handle them all. (See comments 20, 21, 48, 94, 102, 103, 104.)

48. FIRED OUT-ROAD MARCH (100-GUNBN)

This comment is printed when a battery finishes a fire mission and initiates a road march to a better position, or to keep a proper distance from the engaged maneuver units. (See comments 20, 21, 47, 94, 102, 103, 104.)

49. FOUND NO ARTY SPT (55-ASKCONV, ASKIND)

This comment is printed when a unit engaged in combat decides it needs artillery support but finds it has no artillery unit assigned to support it.

50. HOLD AND DIG IN (100-MUZAMOV)

This comment is printed when a company level unit arrives at an objective, whether it be a final objective or intermediate one, and the commander of the company decides to keep the unit in that position because the commander's overall objectives have been met, at least temporarily. (See comments 8, 46, 69, 96, 100.)

51. IGNORES ATK/RETREATS (20-MDIRATK)

This comment is printed when a company is retreating away from combat and is attacked by another unit. The retreating company ignores this attack also and continues to retreat. This comment is generally printed when an arty unit, EW company, or HQ company is attacked while it is trying to get away from an enemy unit it had previously seen. (See comments 18, 88.)

52. INITIATE COMBAT (100-GOTOWAR)

This comment is printed when a unit presently in non-combat status decides to engage in combat.

53. INTEL NET-BUSY W/BKD (0-NETOPEN) See comment 1.

54. INTEL NET-BUSY W/MSG (0-NETOPEN) See comment 1.

55. INTEL NET-INOPERABLE (0-NETOPEN) See comment 1.

56. INTEL NET-JAMMED (0-NETOPEN) See comment 1.

57. INTEL NET-OUT/RANGE (0-NETOPEN) See comment 1.

58. INTEL NET SEC BREAK (100-INTRCPT) See comment 6.

59. INTEL NET-TRANSMIT (30-TRNSMIT) See comment 7.

60. INTERCEPTS ADMIN NET (60-INTRCPT)

This comment is printed when an enemy listening unit intercepts a message being transmitted over an administrative net. The general form of this type comment is:

INTERCEPTS "net type"

The possible net types are the same as those listed under comment 1. The comment immediately preceeding this one specifies the type of message intercepted and which unit was sending it. (See comment 89.)

61. INTERCEPTS ARTY NET (60-INTRCPT) See comment 60.

62. INTERCEPTS CAS NET (60-INTRCPT) See comment 60.

63. INTERCEPTS COM NET (60-INTRCPT) See comment 60.

64. INTERCEPTS INTEL NET (60-INTRCPT) See comment 60.

65. JAMMER TURNED OFF (100-JAMON)

This comment is printed when a jamming unit turns off his jamming equipment. This will occur at the time specified by the user in the interactive jamming order.

66. JAMMER TURNED ON (100-JAMON)

This comment is printed when a jamming unit turns on his jamming equipment. This will occur at the time specified by the user in the interactive jamming order.

67. KILLED IN ACTION (100-NAYDETH)

This comment is printed when a company is rendered combat ineffective due to casualty losses. Usually just prior to this comment will be either a CAS CASUALTIES, COMBAT LOSS, or ARTILLERY CASUALTIES comment.

68. NET FREQ IS 0 (100-JAMCHK)

This comment serves only as a debug message.

69. NONCOMBAT MOVE (35-HEXMOVE)

This comment is printed when a unit not engaged in combat moves from one hex to another. (See comments 8, 46, 50, 96, 100.)

70. NUDET ###### (100-GUNNUC)

This comment shows the hex location of a nuclear detonation.

71. PONDER ARTY REQ (100-MUSEOUT)

This comment is printed wnen a unit is about to ponder a request for artillery support.

72. PONDER CAS REQ (100-MUSEOUT)

This comment is printed when a unit is about to ponder a request for close air support.

73. PONDER COMBAT (100-MUSEOUT)

This comment is printed when a unit is about to ponder a subordinate's combat situation. In particular, such pondering is triggered when a subordinate in combat does not fire for some reason, has run out of ammunition, or moves at a speed outside a prescribed range. (See comments 17, 19, 31, 32, 43, 45, 99.)

74. PONDER ENEMY ATK (100-MUSEOUT)

This comment is printed when a unit is about to ponder a direct fire attack on one of its subordinate, company level units.

75. PONDER ENEMY MOVE (100-MUSEOUT)

This comment is printed when a unit is about to ponder an observation of nearby enemy movement.

76. PONDER INTELL RPT (100-MUSEOUT)

This comment is printed when a unit is about to ponder an intelligence message which has been received. (See comments 83, 84.)

77. PONDER MOVEMENT (100-MUSEOUT)

This comment is printed when a unit is about to ponder a subordinate's arrival at his objective without any further operations orders. (See comments 46, 50, 100.)

78. PONDER NEW ORDER (100-MUSEOUT)

This comment is printed when a command unit is about to ponder a new operations order which has been received. (See comment 95.)

79. PONDER PLAN (100-MUSEOUT)

This comment is printed when a company level unit is about to ponder the planning of a new operation specified in new orders. (See comment 97.)

80. PONDER STATUS RPT (100-MUSEOUT)

This comment is printed when a unit is about to ponder a status report which has been received from a subordinate. (See comment 98.)

81. PRESENT STATUS (100-ECHOUT)

When a timeout is scheduled, the status of the units in the scenario is printed out and this comment refers to a unit's present status. The same comment is used for both company level units and command units at a higher echelon.

82. PROCESS CAS REQUEST (100-CASREQ)

This comment is printed when the corps DASC (Direct Air Support Center) processes a request from a maneuver unit for close air support.

83. REC BN-LEVEL INTELL (100-MINTLHI)

This comment is printed when a command unit receives an intelligence message concerning a battalion level enemy unit.

84. REC CO-LEVEL INTELL (100-MINTLOW)

This comment is printed when a command unit receives an intelligence message concerning a company level enemy unit.

85. REQ CLOSE AIR SPT (100-ASKCAS)

This comment is printed when a unit decides to request close air support as a result of losses it has taken in combat.

86. REQ NUKE ARTY (100-ASKNUKE)

This comment is printed when a company level unit requests a nuclear fire mission against an enemy unit.

87. REQUEST ARTY (30-ASKCONV,ASKIND)

This comment is printed when a unit requests conventional artillery fires on an enemy company level unit.

88. RETREATS FROM ENEMY (50-MZENMUD)

This comment is printed when a company level unit, which is not an HHC, artillery battery, or EW company, which is already in a panic mode, sees a nearby enemy unit. The company level unit will continue to retreat from the conflict. (If the unit is not in a panic mode, it will then consider whether or not to engage the enemy unit in combat.) (See comments 18, 51.)

89. SENDS ARTY REQUEST (60-INTRCPT)

This comment is printed when an artillery support request message is intercepted by the enemy. The remaining information on this line of output refers to the unit sending the message. The general form of this type comment is:

SENDS "message type"

There are 5 possible message types:

ARTY REQUEST	Artillery support request
CAS REQUEST	Close air support request
INTELL REPORT	Intelligence report
OP ORDER	Operations order
STATUS REPORT	Unit status report

The comment immediately following this one specifies the type of net on which the message was sent and which enemy unit intercepted it. (See comment 60.)

90. SENDS CAS REQUEST (60-INTRCPT) See comment 89.

91. SENDS INTELL REPORT (60-INTRCPT) See comment 89.

92. SENDS OP ORDER (60-INTRCPT) See comment 89.

93. SENDS STATUS REPORT (60-INTRCPT) See comment 89.

94. SHORT ON AMMO (100-GUNBTRY)

This comment is printed when an artillery battery runs low on ammunition and cannot fire an artillery request. (See comments 20, 21, 47, 48, 102, 103, 104.)

95. STARTING TO PLAN OPN (100-MZNEWOR)

When a command unit receives an operations order and decides to plan an operation for his subordinates, this comment is printed. (See comment 97.)

96. START NONCMBT MOVE (100-PARADE)

When a company level unit, which has been stopped, and is not in combat at the present time, starts moving, this comment is printed. (See comments 8, 46, 50, 69, 100.)

97. START OF PHASE (100-MUZPLAN)

As a result of planning an operation this comment is printed for the company level units that the commander directly supervises. (See comment 95.)

98. STATUS RPT RECEIVED (45-MSTRPT)

This comment is printed when a commander receives a status report from one of his subordinates.

99. STOP AND DIG IN (100-CBTFIR)

When a unit in combat does not fire for some reason, does not break and run, cannot see any nearby enemy units, and is defending, then the unit will get out of combat and set up a defensive position at its current location, and this message is printed. (See comments 17, 19, 32, 43, 45.)

100. STOPPED AT PHASELINE (100-MUZAMOV)

When a unit on the attack reaches the phaseline that his commander has been told to attain, the unit will stop and this comment is printed. (See comments 8, 46, 50, 69, 96.)

101. TRY ALTERNATE NET (0-ESTLINK)

This comment is printed when a unit tries to send a message on an alternate net because it can't get through on the primary net.

102. WILL NOT CATCH UP (100-FDCMOVE)

If an artillery battalion fire direction center, in support of an attacking force, decides not to move any batteries because they are already in proper position, this comment is printed. (See comments 20, 21, 47, 48, 94, 103, 104.)

103. WILL NOT MOVE BTRY (10-FDCMOVE)

If an FDC, in support of either an attacking force or a defending force, decides not to move any batteries because too many are already moving, this comment is printed. (See comments 20, 21, 47, 48, 94, 102, 104.)

104. WILL NOT ROAD MARCH (100-FDCMOVE)

If an FDC, in support of a defending force, decides not to move any batteries because they are already in proper position, then this comment is printed. (See comments 20, 21, 47, 48, 94, 102, 103.)

105. ZERO STATION (100-NETOPEN)

This comment serves only as a debug message.

106. ZERO TRANS TIME (100-TRNSMIT)

This comment serves only as a debug message.

APPENDIX C
UOIL GRAMMAR

C.1 INTRODUCTION

This appendix provides a brief description of the structure or grammar of the User Oriented Input Language (UOIL). This language was developed for the METRIC family of simulations to enable the user to describe the units comprising the combat scenario with English-like sentences. A general overview of UOIL, along with a typical input example, is presented in Section 2.

C.2 GRAMMAR RULES

At the end of this section is a set of rules which abstractly define UOIL. The rules are presented in the well-known BNF (Backus-Naur Form) used by computer scientists to define languages.

A BNF definition of a language is given in terms of the structures which make up the language. A structure is identified by enclosing the name of the structure between the symbols < and >. For example, a sentence may be identified by writing < SENTENCE >. BNF defines higher level structures in terms of lower level structures. For example, to indicate that a sentence consists of a subject followed by a predicate, one could write

< SENTENCE >: = < SUBJECT > < PREDICATE >.

Sometimes there are a number of possible ways to form a structure, and in this case the symbol | is used to indicate "or". If, for example, the subject of a sentence is always either a noun or a pronoun, then one could write

< SUBJECT >: = < NOUN > | < PRONOUN >.

At some point lower level structures must be defined in terms of the actual words or symbols that appear in the language. These are written without the symbols < and > . For example, if the only pronouns allowed in the language are he, she, and it, one could write

< PRONOUN >: = HE|SHE|IT.

When using UOIL, one should be aware of the following points:

(1) Only one UOIL sentence is permitted per card;

(2) The format on each card is free; i.e., the sentence may be located anywhere on the card. (It is convenient to use indentation to highlight levels of command);

(3) Spaces (represented by Δ) are required between words;

(4) A period is required at the end of each sentence.

C.3 UOIL GRAMMAR

```
<S>             : =  <STORY>   EOR      (EOR is an end of record marker.)
                                        (<S> is the goal symbol of the
                                        grammar.)
 <STORY>        : =  <SENTENCE>  |   <STORY>   <SENTENCE>
<SENTENCE>      : =  <C2STMT>. |<LOCSTMT>. |<MATRLSTMT>.
<C2STMT>        : =  <COLOR>  | <SIDE>  | <NATIONALITY>|
                     <UNITDESC>  Δ  <VERBCOMMAND>  Δ  <UNITDESC>
<LOCSTMT>       : =  <UNITDESC>  Δ  IS Δ AT Δ HEX  Δ  <NUMBER>  Δ
<MATRLSTMT>     : =  <UNITDESC>  Δ  HAS  Δ   <MATPHR1>
<MATPHR1>       : =  <MATPHR>   |   <MATPHR1> ,   <MATPHR>
<MATPHR>        : = <NUMBER>   Δ   <MATITEM>|
                     <NUMBER>  Δ  <MATITEM>  Δ OF Δ TYPE Δ  <NUMBER>  Δ
<UNITDESC>      : =  <NUMBER>  Δ   <UNITTYPE>
<VERBCOMMAND>   : =   C  |  CMDS  |  COMMANDS
<COLOR>         : =   BLUE  |  RED
<SIDE>         : =    NATO  |  WP  |  PACT
```

(Note that in the following definitions, an underscored portion of a word is a valid abbreviation.)

The following nationalities are permitted (grouped by country):

```
<NATIONALITY>   : =  US | GB, UK, or BR | WGR, BRD, GE, or FRG | DANISH|
                     DUTCH or NL |  ITALIAN| FRENCH|BELG |  CAN |  RUSSIAN,
                     SO, or SU| EGR or DDR |  CZECH |  HUNG | POLISH | RUM or
                     RO
```

<NUMBER> : = Any integer. For hexes, this must be a valid hex address. When associated with a <UNITTYPE> it is the unit number; e.g., for 5th CORPS, <NUMBER> := 5. For material items (<MATITEM>) it is the quantity of that material.

<MATITEM> : = INFANTRY, APCS, or ATUS | TANKS | TUBES | ROCKETS | ROUNDS | AIRNUKES | GROUNDNUKES | RADIOS

<UNITTYPE> Unit types are displayed by level. Units command other units of a lower level, and every unit must command at least one level 3 unit. Only level 3 units may have material or a location. Units above this level derive their positions and material by aggregating their subordinates' positions and material.

LEVEL	PERMISSIBLE UNIT TYPES
7	CORPS, CAA, MRCORPS, ARTYCORPS, ARMORCORPS, TA, AGCORPS, AGCAA, AGTKA
6	DIV, ARTYDIV, CORPSARTY, CORARTY, AGMISLGRP, AGCORARTY, AGARTYDIV, COSCOM, MECHDIV, MRDIV, AGDIV, AGINFDIV, AGMECHDIV, AGABNDIV, AGMTNDIV, AGMRDIV, AGCAA, AIRCAVGRP, ARMORDIV, ARMDIV, TKDIV, AGARMDIV, AGTKDIV, AGTKA, AGCORPSHQ, AGCAAHQ, AGTKAHQ
5	BDE, RGT, DISCOM, ARTYBDE, DIVARTYGP, ARTYRGT, DIVARTY, MISLBDE, AGBDE, RECRGT, ACR, AGCAVBDE, AGABNRGT, MECHBDE, MRRGT, AGINFBDE, AGMECHBDE, AGMRRGT, ARMORBDE, ARMBDE, TKRGT, AGARMBDE, AGTKRGT
4	BN, SQN, SQDN, ARTYBN, MRLBN, MISLBN, RECBN, ACS, AIRCAVTF, MECHBN, MRBN, ARMORBN, ARMBN, TKBN

3 CO, BTY, BTY152, BTY130, BTY122, BTRY, HJBTY. LANCEBTY, BTY203, BTY105. BTY175, BTY155, FROGBTY. SCUDBTY, MRLBTY, RECCO, ACT, MRCO. MECCO, MCSCO, AIRRFLTM, AIRWPNTM, ARMCO, TKCO, AACSOCO, HHB. HHC, HHT, CORHQFWD, CORHQREAR, CORHQALT. CORHQMAIN, ARMYHQFWD, ARMYHQREAR, ARMYHQALT. ARMYHQMAIN, DIVHQFWD, DIVHQREAR, DIVHQALT. DIVHQMAIN, BDEHQFWD, BDEHQREAR. BDEHQALT. BDEHQMAIN, RGTHQFWD, RGTHQREAR, RGTHQALT, RGTHQMAIN

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Air Force Systems Command
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Headquarters Space Division
Air Force Systems Command
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Headquarters Space Division
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Strategic Air Command
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